US009062502B2

(12) **United States Patent**
King

(10) **Patent No.: US 9,062,502 B2**
(45) **Date of Patent: Jun. 23, 2015**

(54) **PDC DISC CUTTERS AND ROTARY DRILL BITS UTILIZING PDC DISC CUTTERS**

(75) Inventor: **William W. King**, Houston, TX (US)

(73) Assignee: **Varel International Ind., L.P.**, Carrollton, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 297 days.

(21) Appl. No.: **13/548,449**

(22) Filed: **Jul. 13, 2012**

(65) **Prior Publication Data**

US 2013/0014999 A1 Jan. 17, 2013

Related U.S. Application Data

(60) Provisional application No. 61/507,503, filed on Jul. 13, 2011.

(51) **Int. Cl.**

E21B 10/58	(2006.01)
E21B 10/12	(2006.01)
E21B 10/52	(2006.01)

(52) **U.S. Cl.**
CPC ***E21B 10/12*** (2013.01); ***E21B 10/52*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 10/32; E21B 10/42; E21B 10/55; E21B 10/58
USPC 175/426, 427, 434, 435, 373, 351, 352, 175/382, 384, 391; 76/108.1, 108.4
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,122,787	A *	12/1914	Moore	76/108.1
2,889,138	A	6/1959	Haglund	
3,981,370	A *	9/1976	Bingham et al.	175/373
4,690,691	A *	9/1987	Komanduri	51/293
4,830,123	A *	5/1989	Daly et al.	175/431
5,103,922	A *	4/1992	Jones	175/429
5,201,376	A	4/1993	Williams	
5,232,320	A *	8/1993	Tank et al.	408/145
5,626,201	A *	5/1997	Friant et al.	175/365
5,706,906	A	1/1998	Jurewicz et al.	
6,241,036	B1 *	6/2001	Lovato et al.	175/432
6,454,024	B1 *	9/2002	Nackerud	175/57
6,460,631	B2	10/2002	Dykstra et al.	
6,691,803	B2 *	2/2004	Nackerud	175/57

(Continued)

OTHER PUBLICATIONS

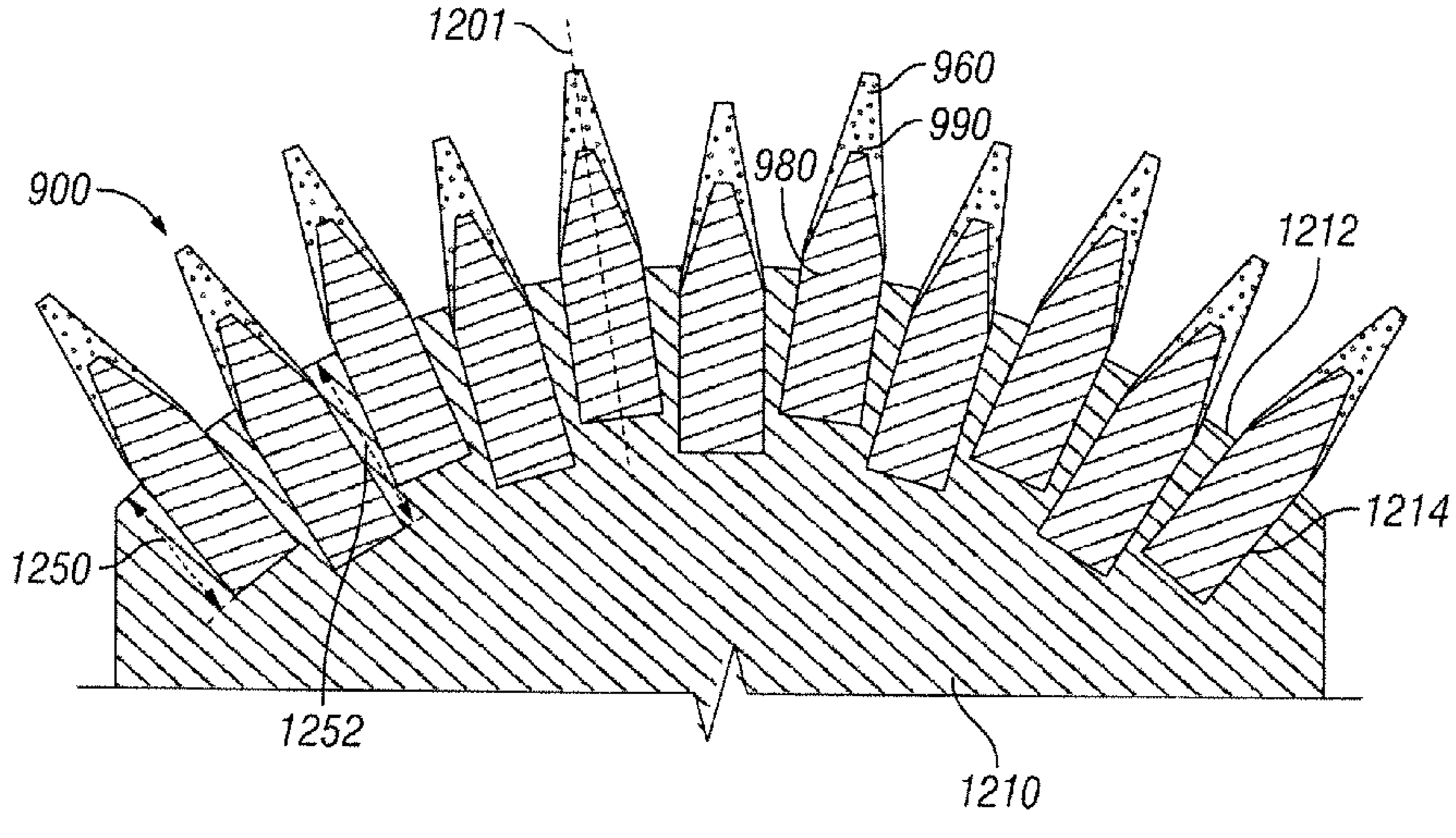
Copenheaver, Blaine R, International Search Report and Written Opinion of the International Searching Authority for PCT/US2012/046628, Oct. 5, 2012, pp. 1-17.

Primary Examiner — Kenneth L Thompson
(74) *Attorney, Agent, or Firm* — King & Spalding LLP

(57) **ABSTRACT**

A disc cutter and a downhole tool including disc cutters therein. The disc cutter is disc-shaped and includes a lower portion and an upper portion. The lower portion is fabricated using a substrate material. At least a portion of the upper portion's perimeter is fabricated using at least one of polycrystalline diamond, synthetic diamond grit, natural diamond grit, and cubic boron nitride. According to certain exemplary embodiments, the disc cutter also includes an intermediate layer, which is fabricated from the substrate material, extending outwardly from at least a portion of the lower portion to a distal end positioned within the upper portion. In alternative exemplary embodiments, the disc cutter is disc-shaped and includes an inner portion made of substrate material, an outer portion made of at least one of polycrystalline diamond, synthetic diamond grit, natural diamond grit, and cubic boron nitride, and a channel extending orthogonally through the inner portion.

31 Claims, 9 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,695,074	B2 *	2/2004	Nackerud	175/57
6,843,333	B2	1/2005	Richert et al.	
6,959,774	B2 *	11/2005	Nackerud	175/267
2010/0000800	A1	1/2010	Chen et al.	
2010/0219000	A1	9/2010	Doster	
2010/0320001	A1	12/2010	Kulkarni	
2011/0031036	A1	2/2011	Patel	
2011/0259150	A1 *	10/2011	Hall et al.	76/115

* cited by examiner

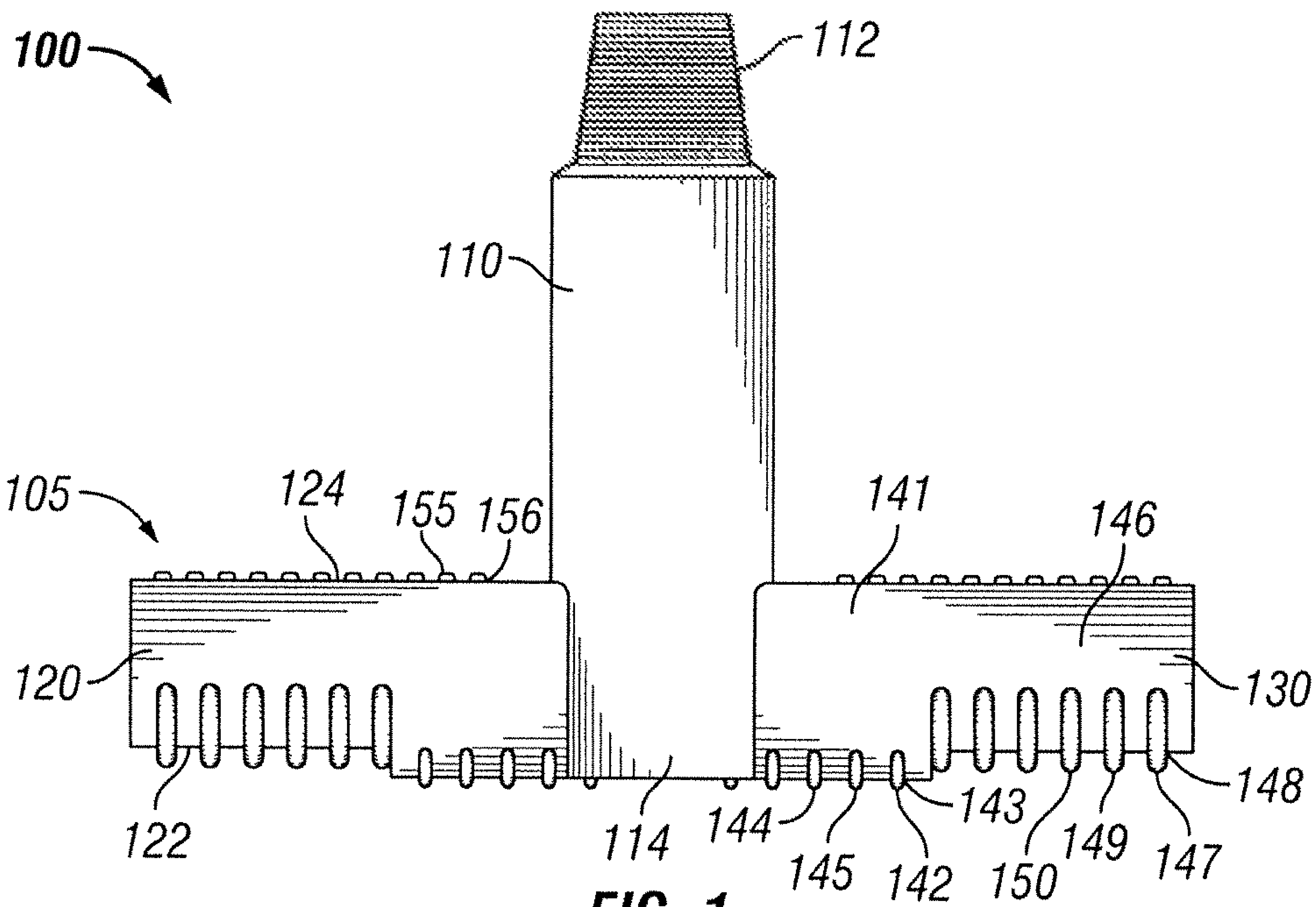


FIG. 1
(Prior Art)

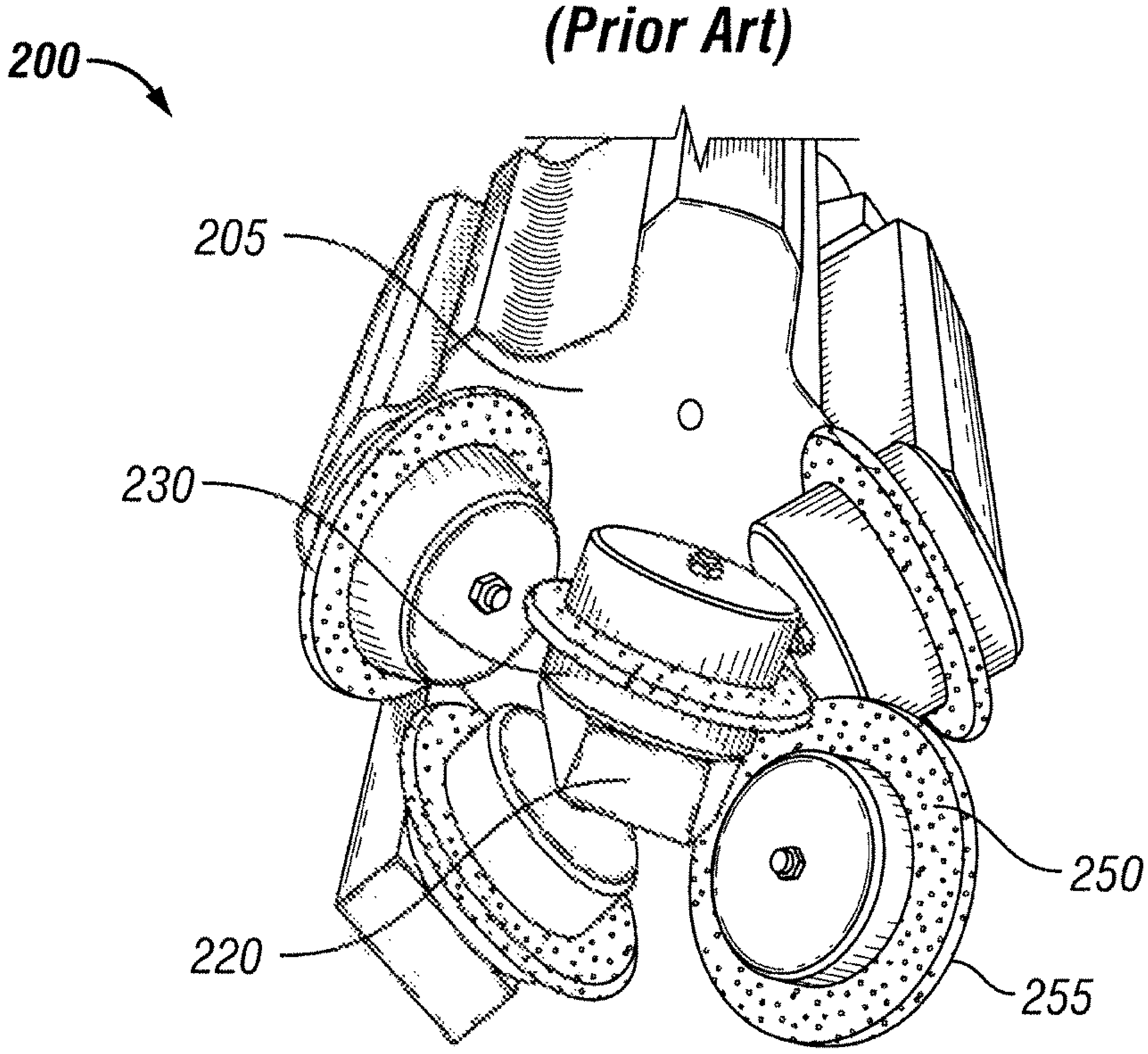


FIG. 2
(Prior Art)

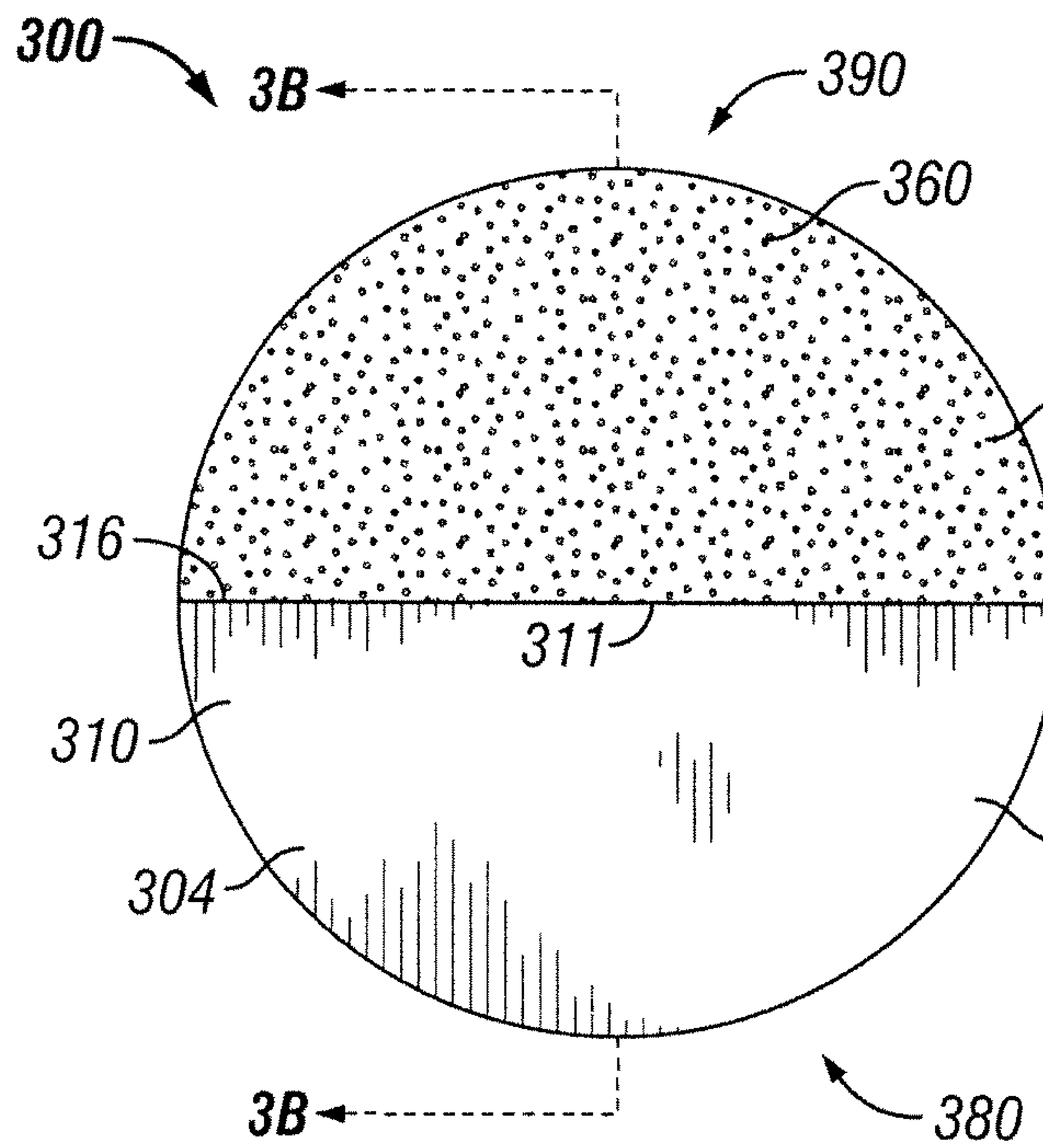


FIG. 3A

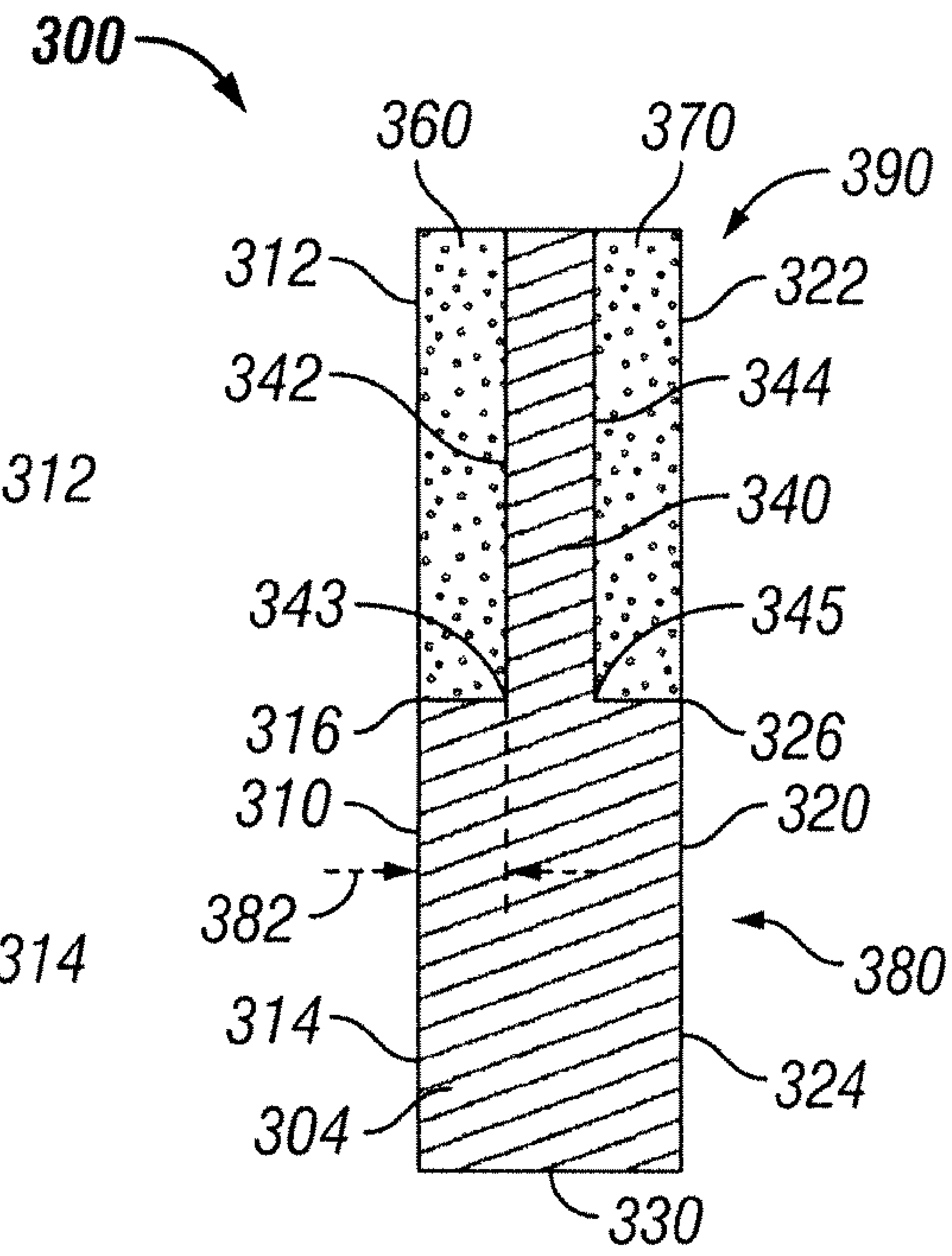


FIG. 3B

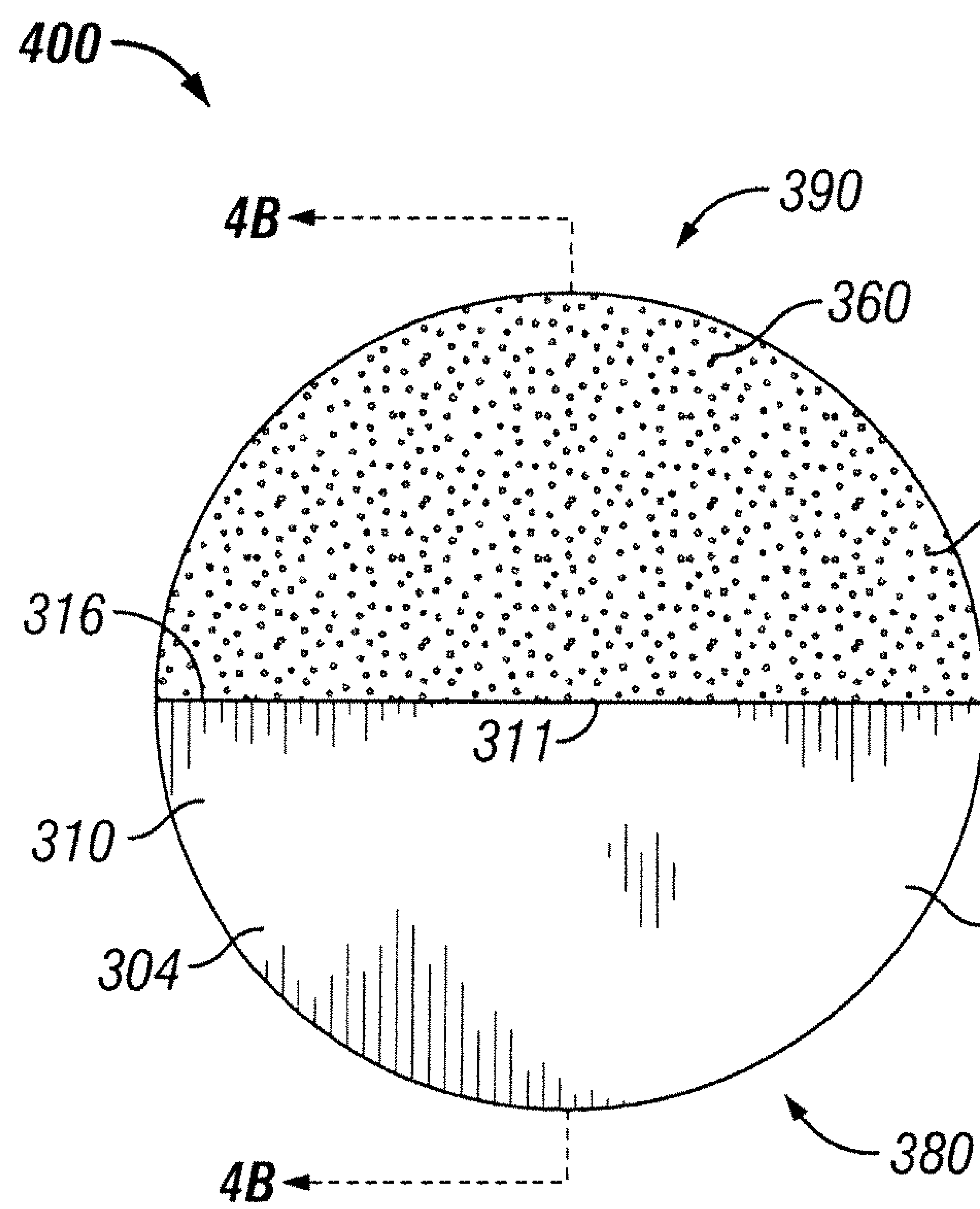


FIG. 4A

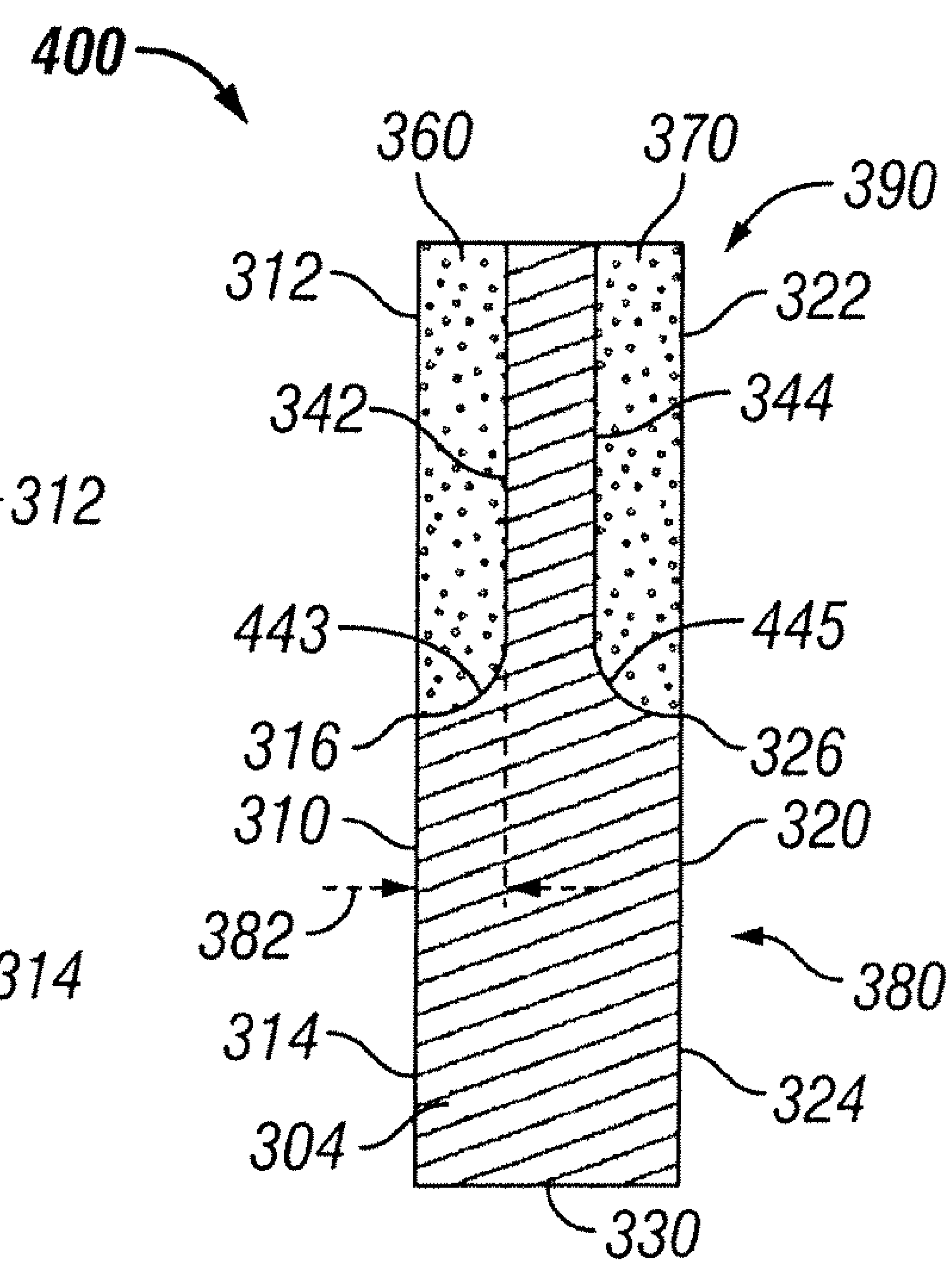


FIG. 4B

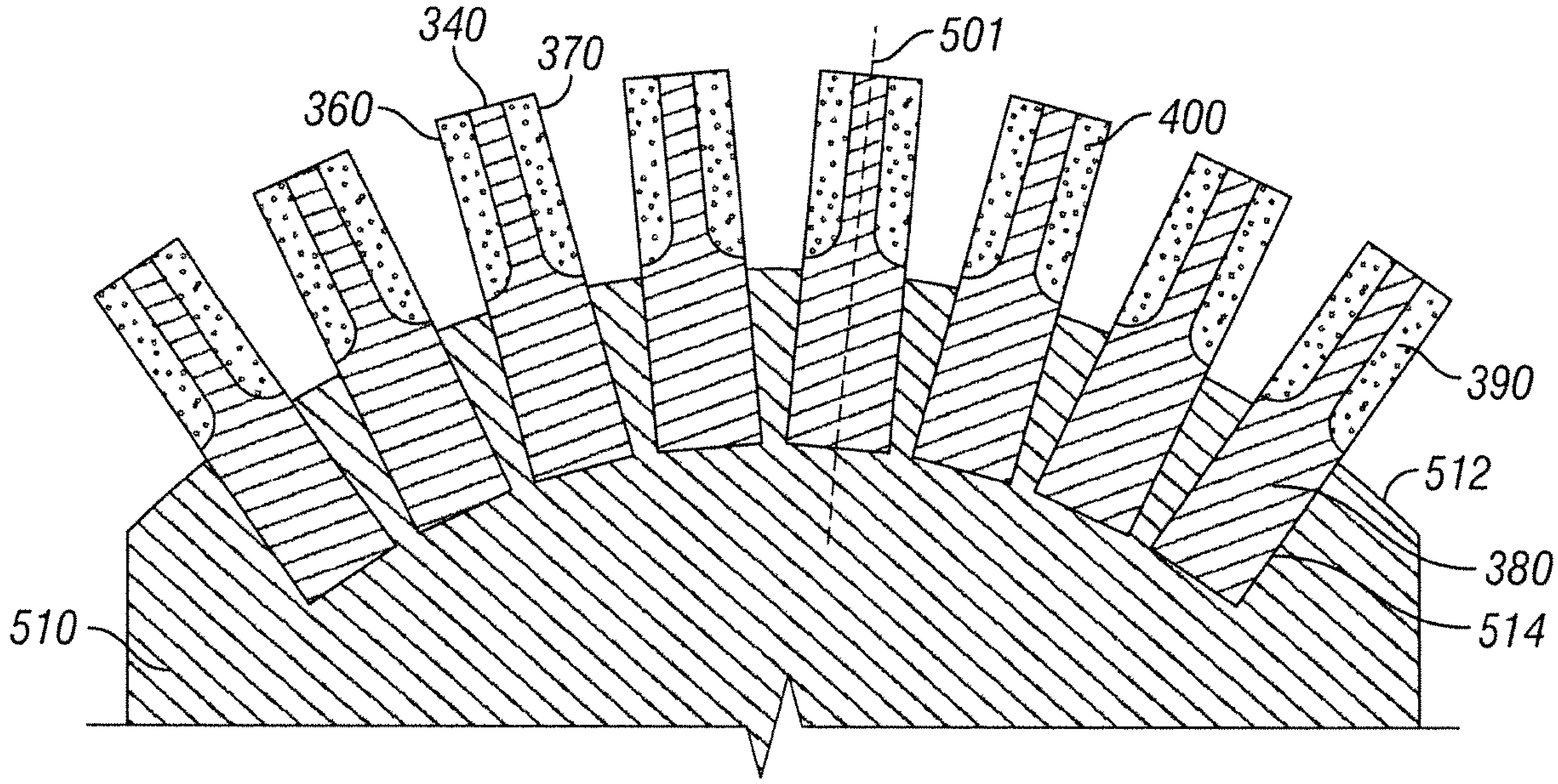

340
370
501
360
400
390
512
380
510
514

FIG. 5A

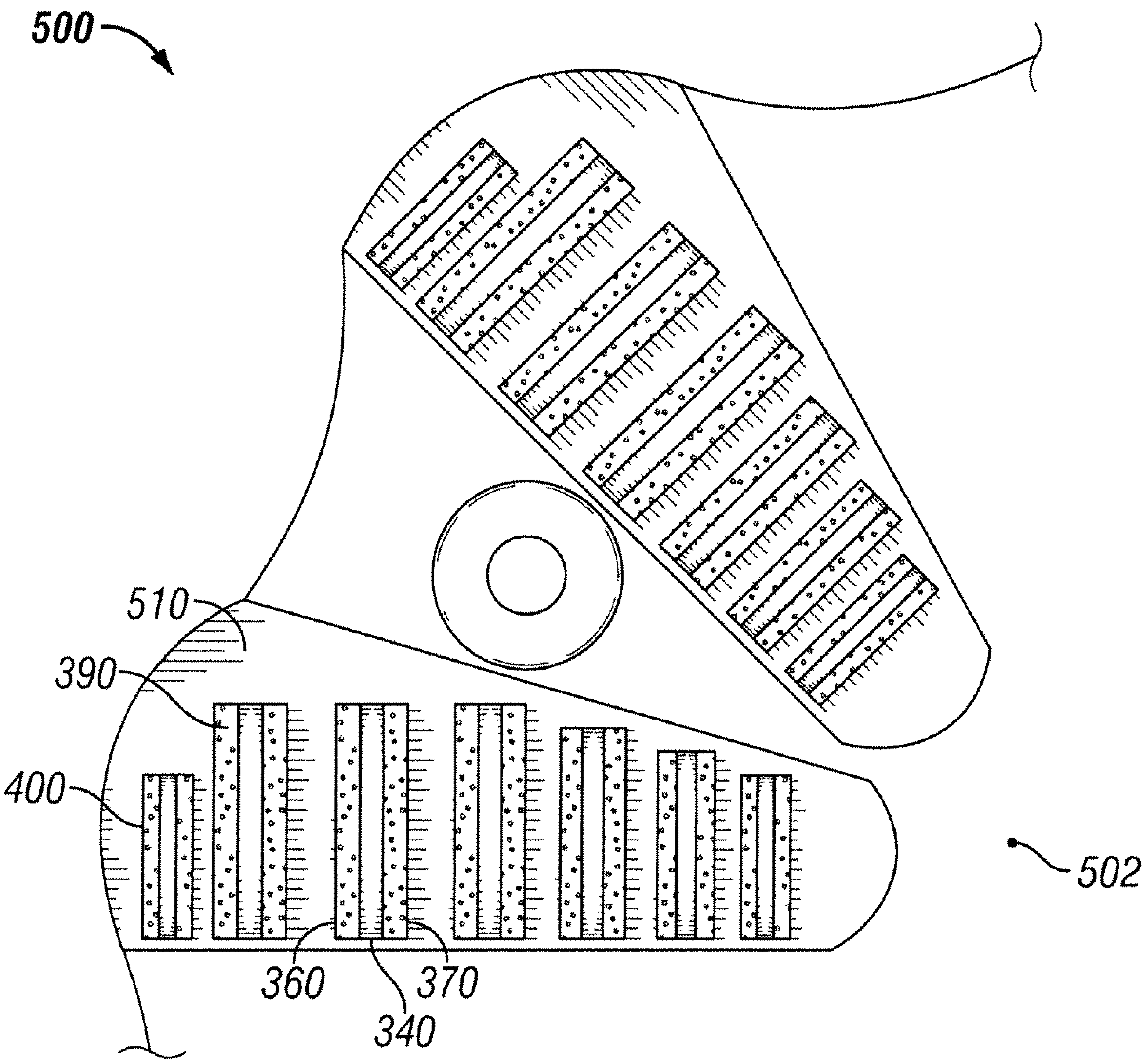

500
510
390
400
502
360
370
340

FIG. 5B

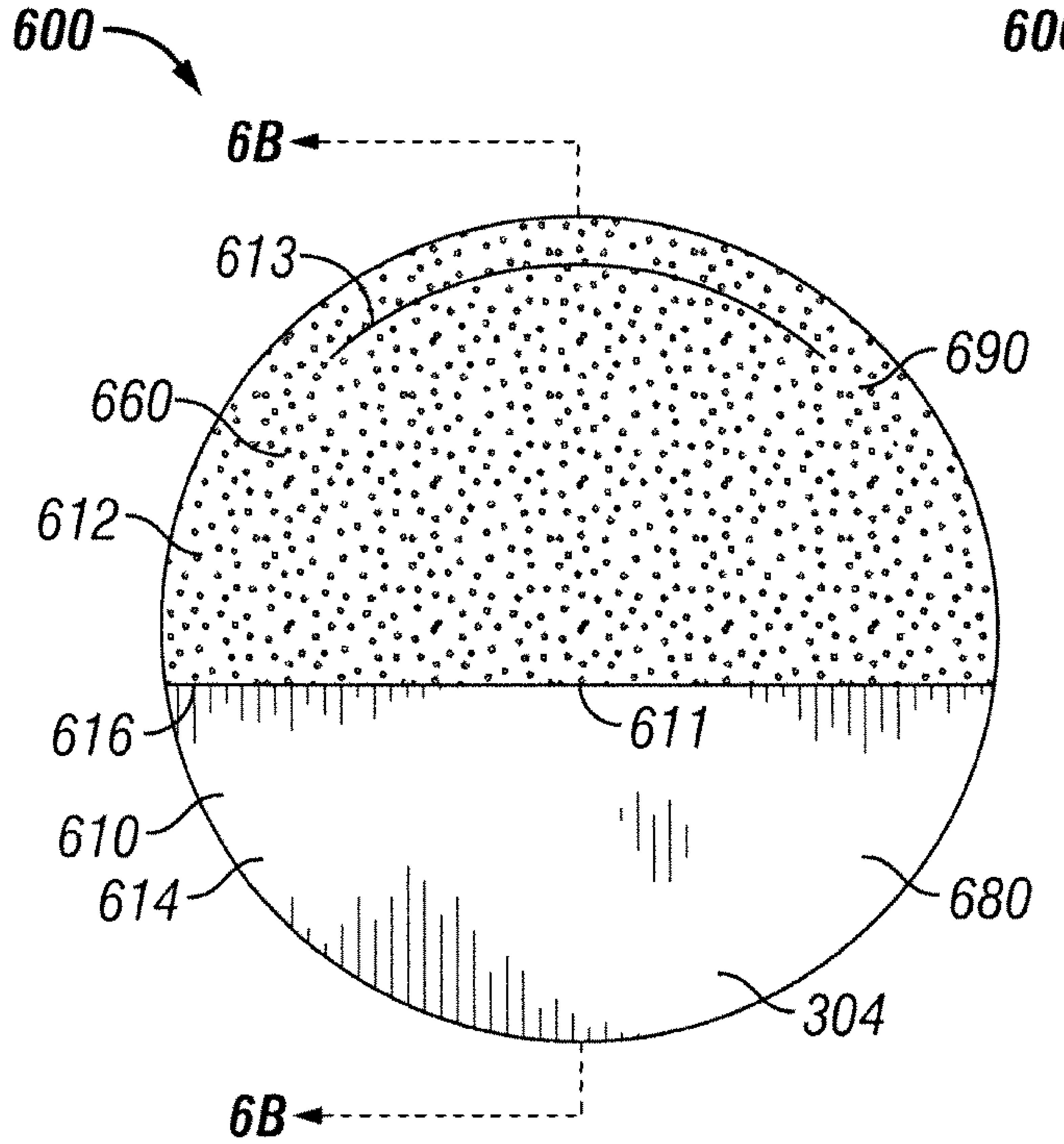


FIG. 6A

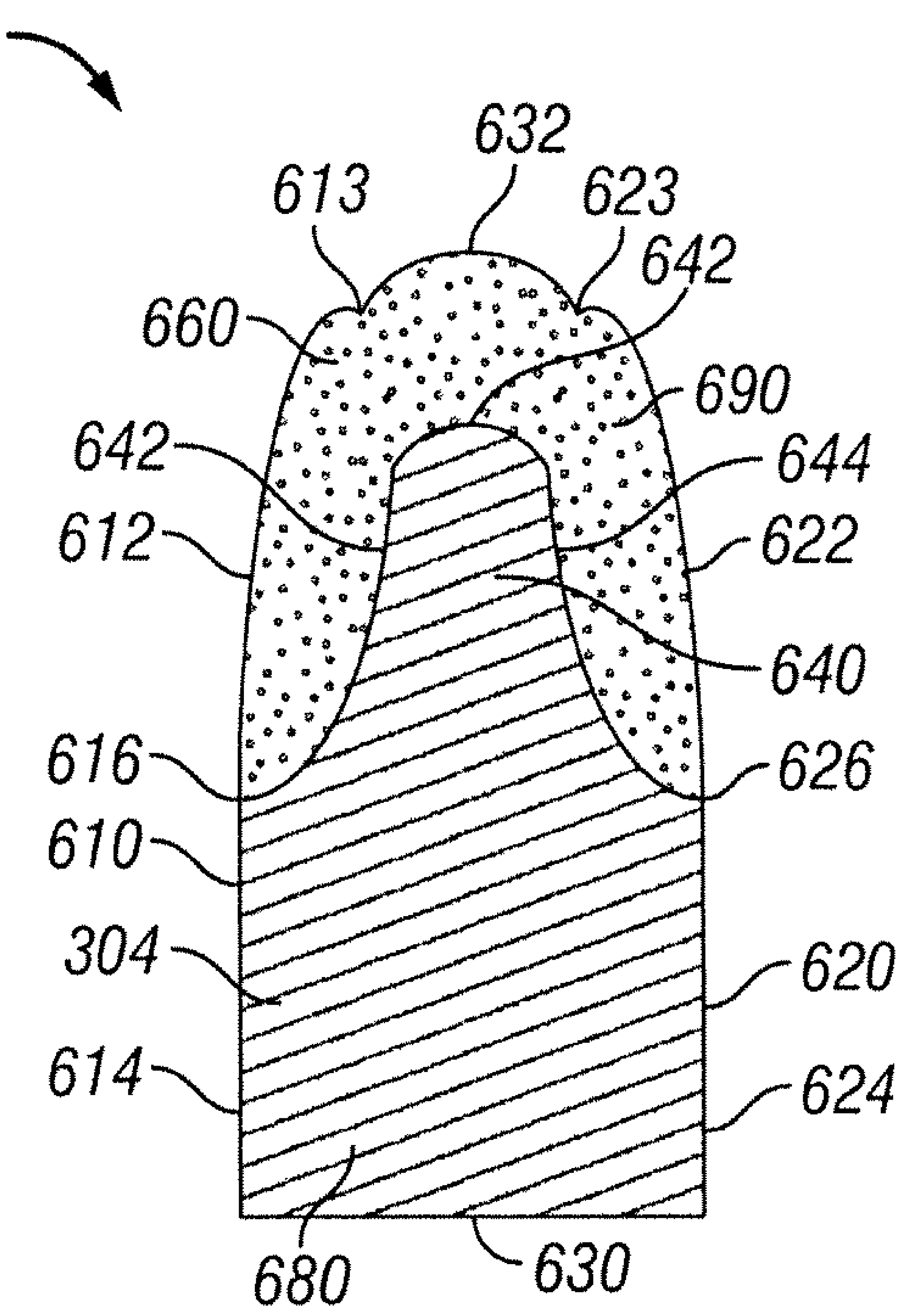


FIG. 6B

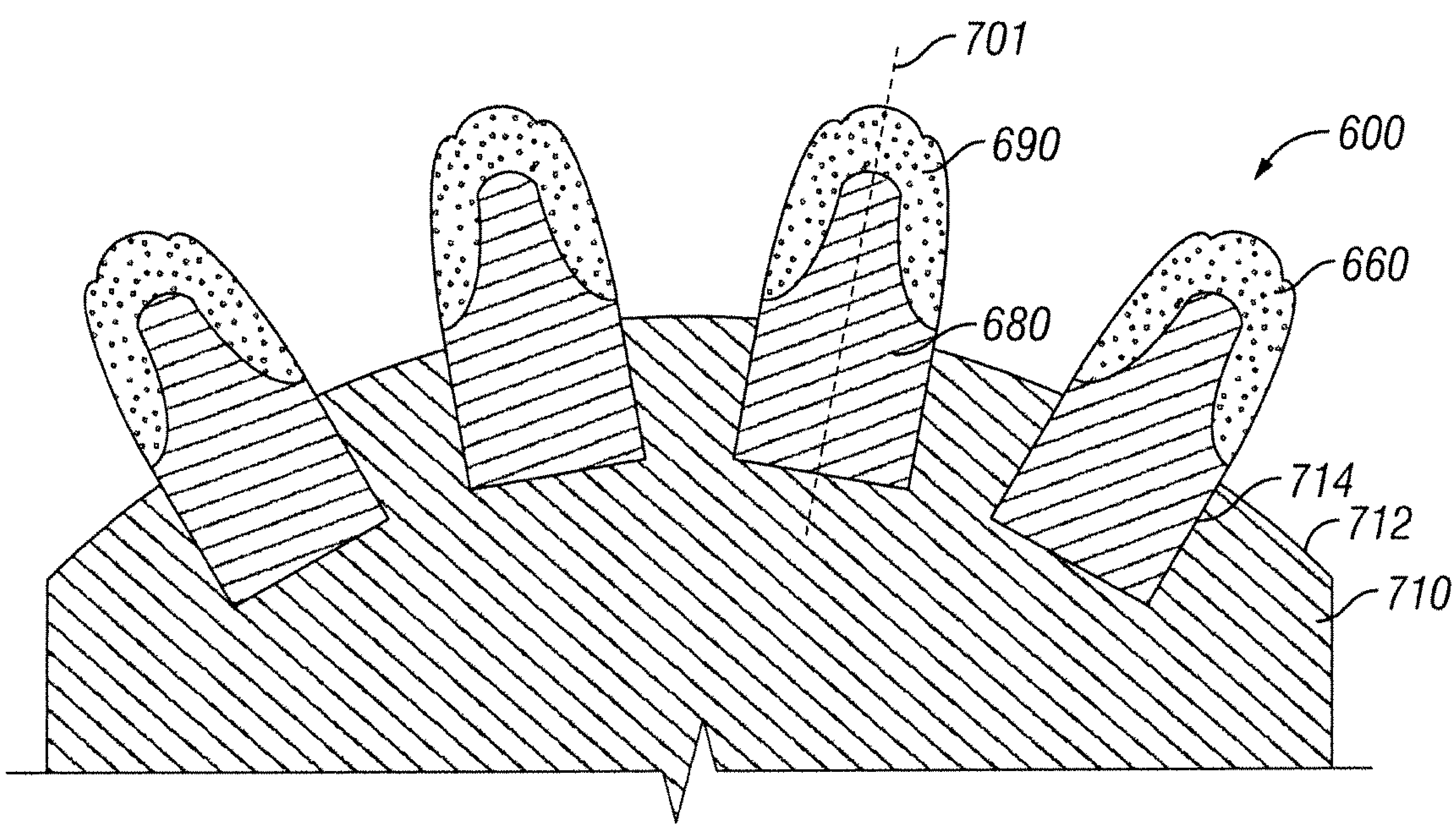


FIG. 7

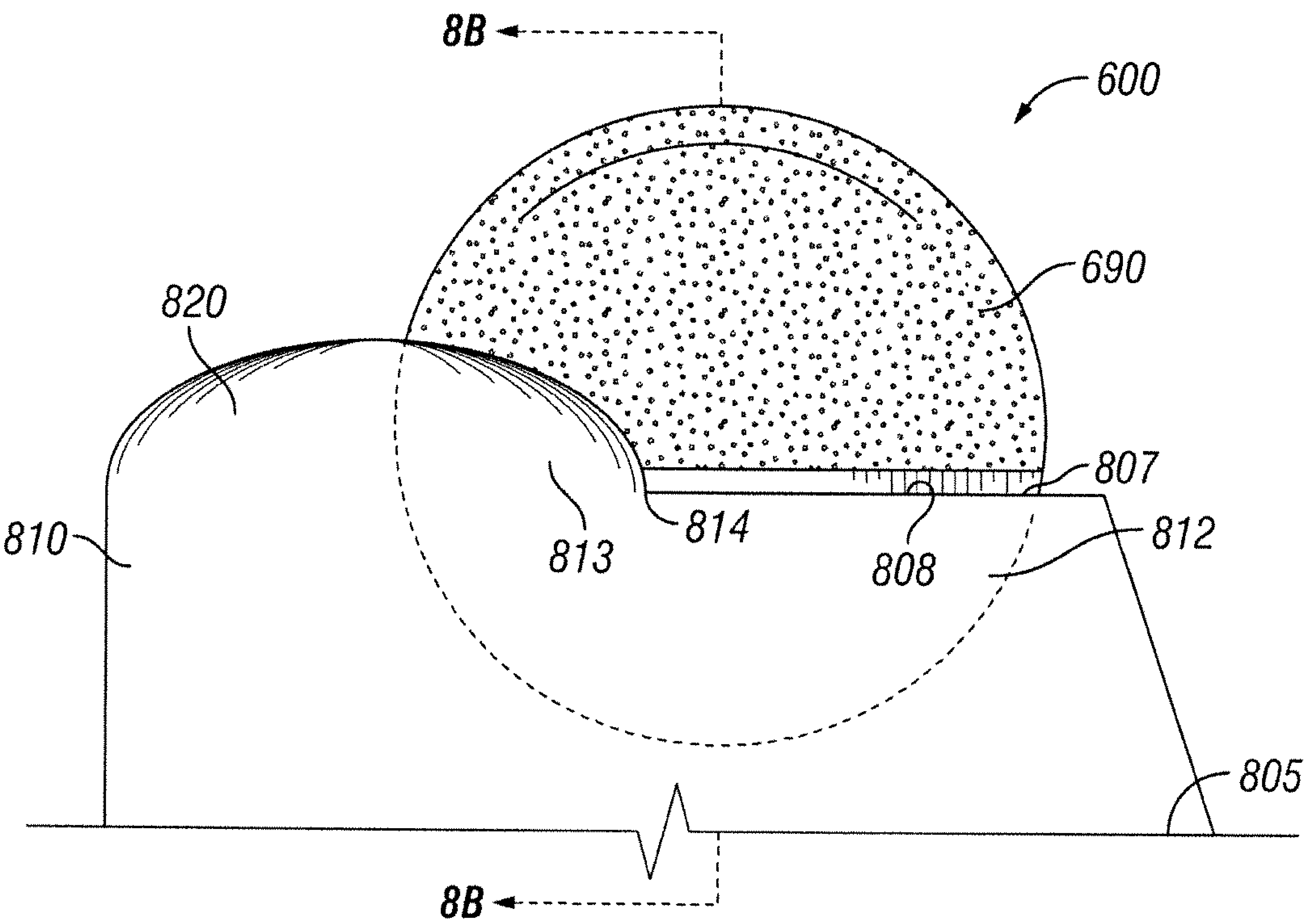

8B
600
690
820
807
810
814
812
813
808
805
8B

FIG. 8A

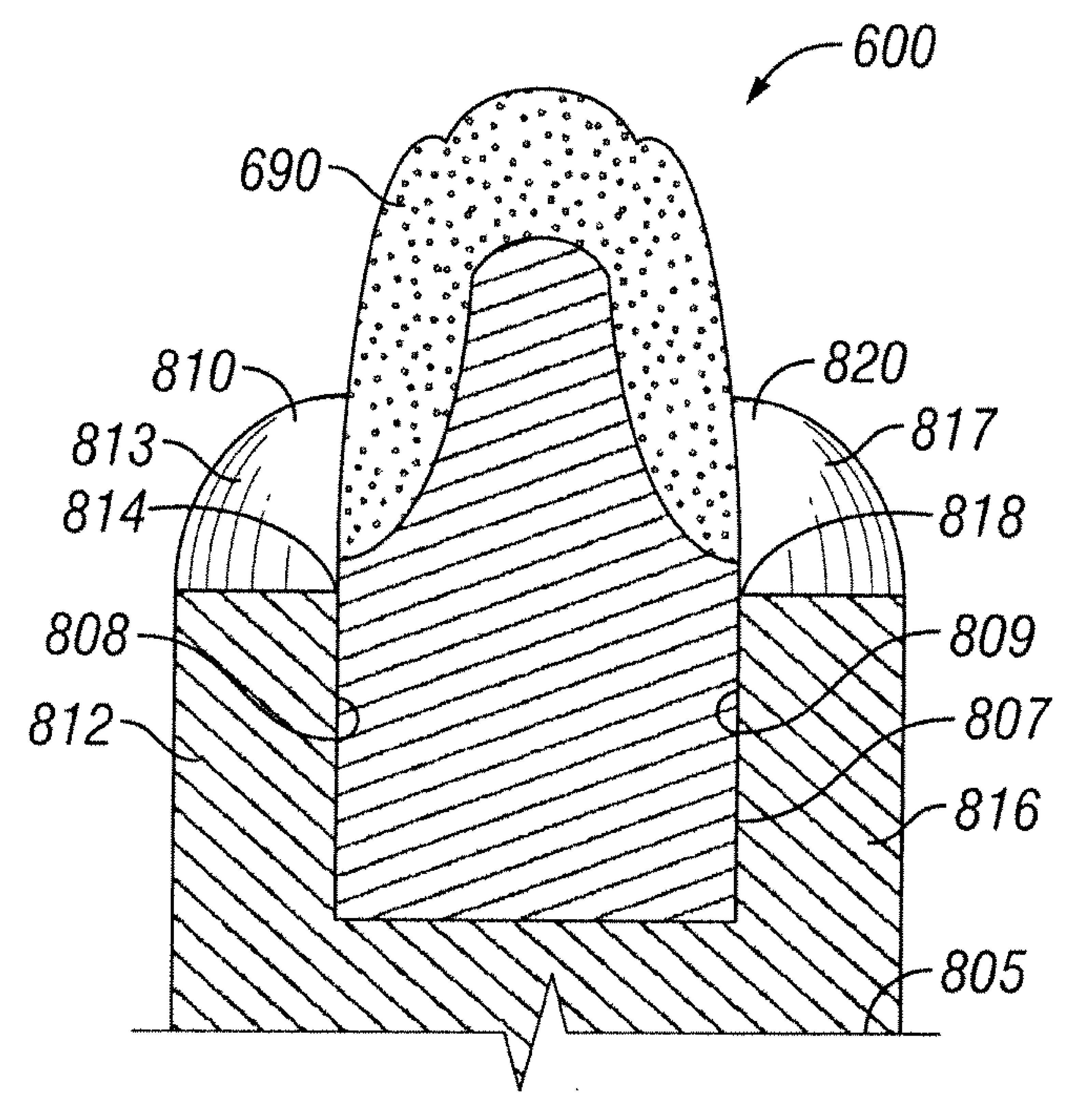

600
690
810
820
813
817
814
818
808
809
812
807
816
805

FIG. 8B

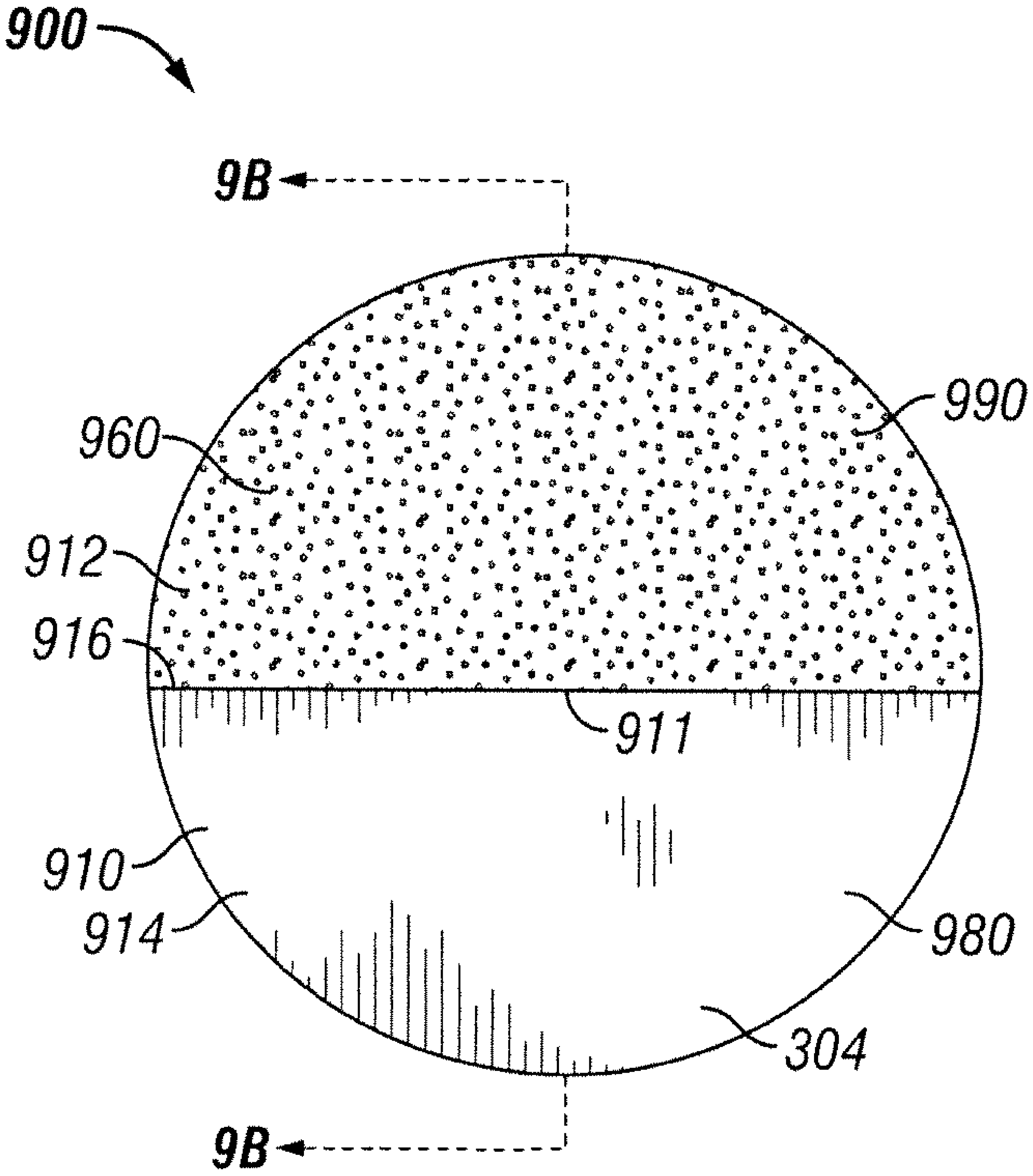


FIG. 9A

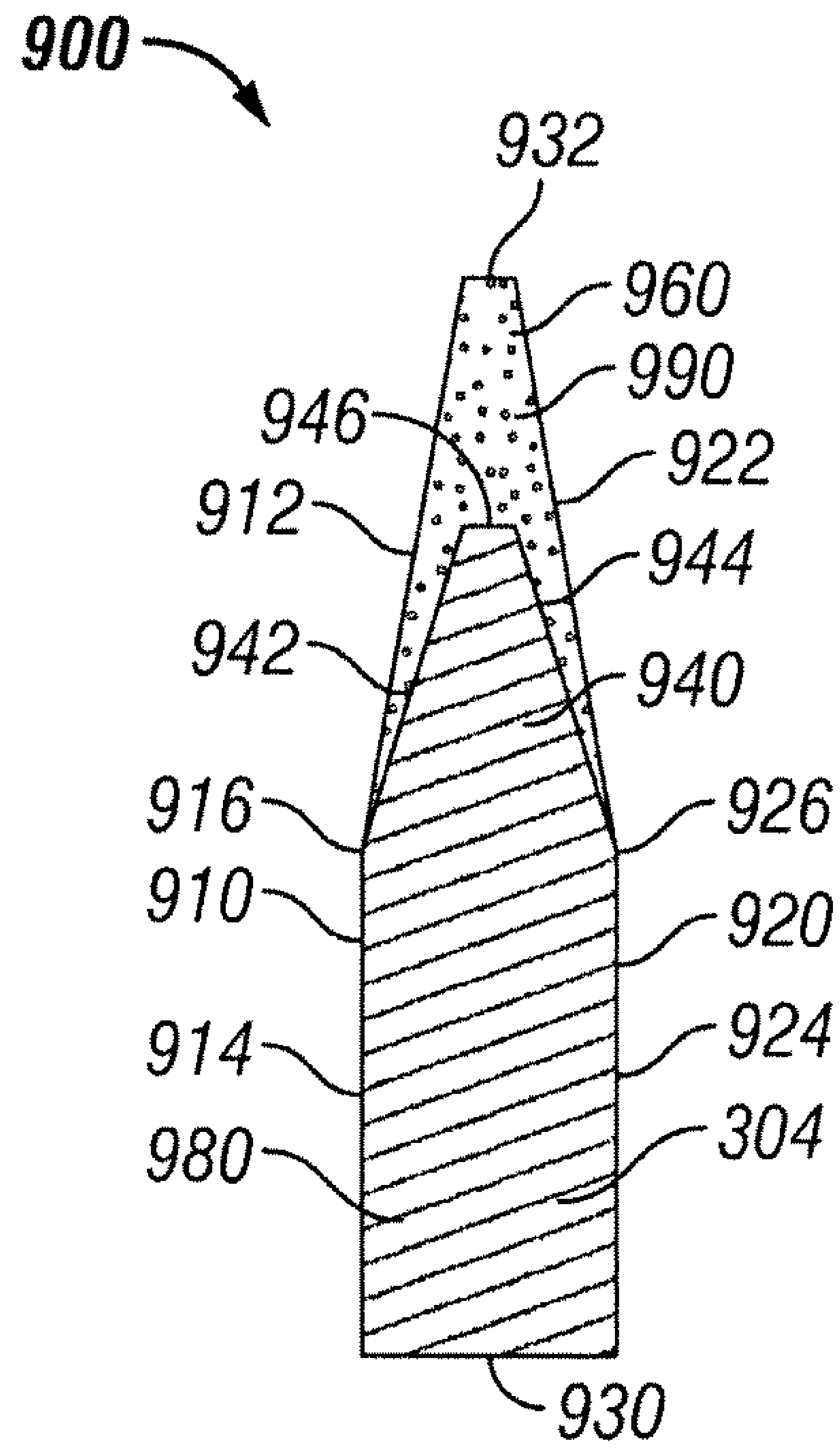


FIG. 9B

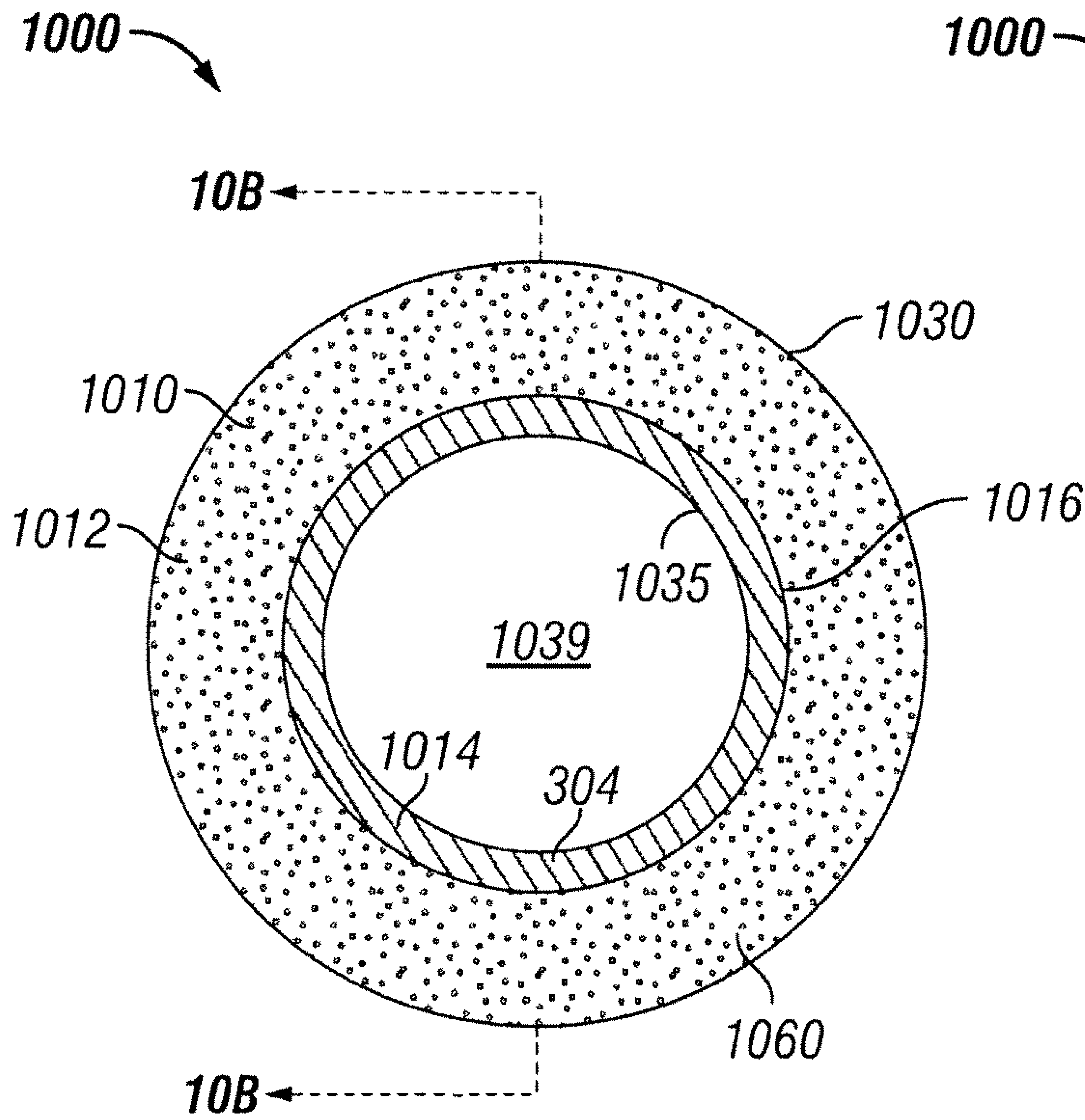


FIG. 10A

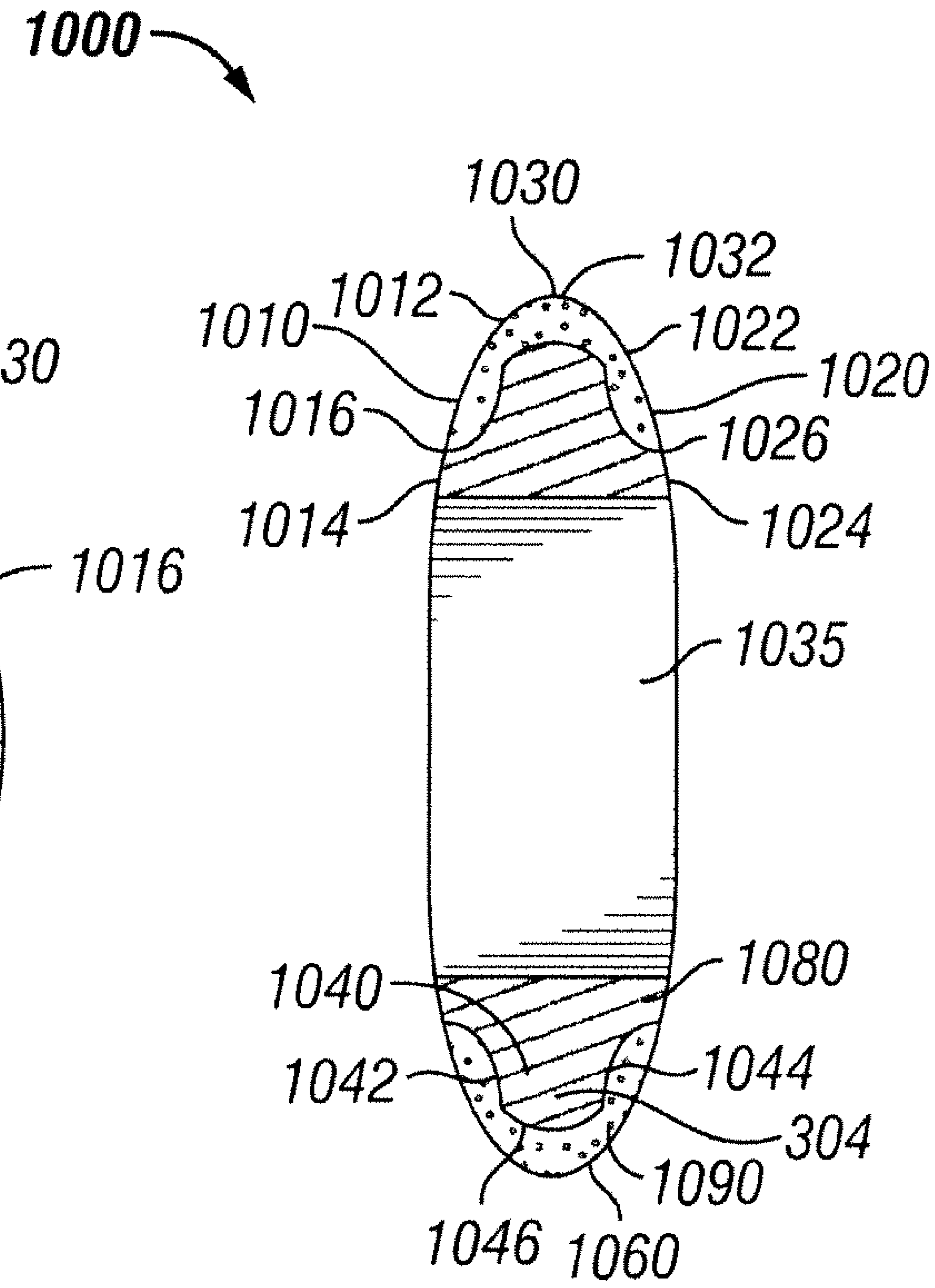


FIG. 10B

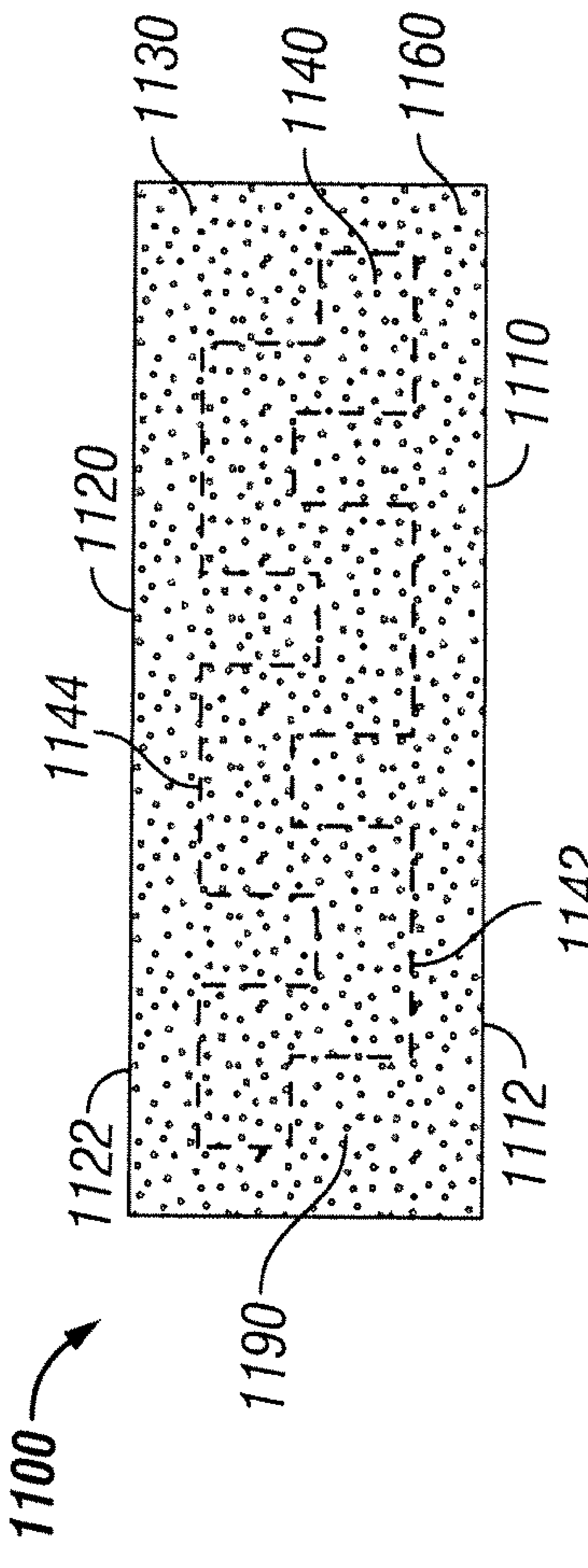


FIG. 11A

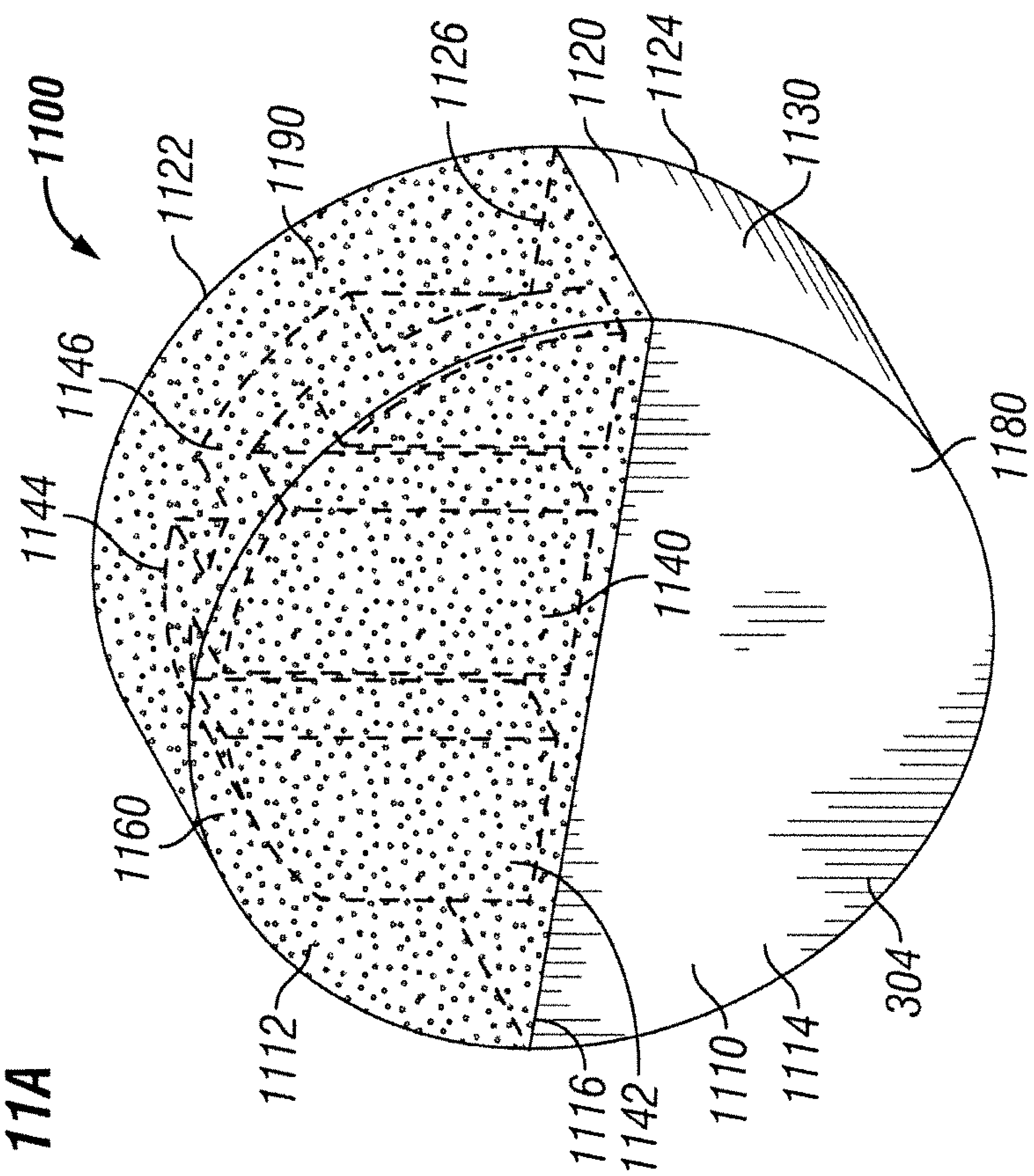


FIG. 11C

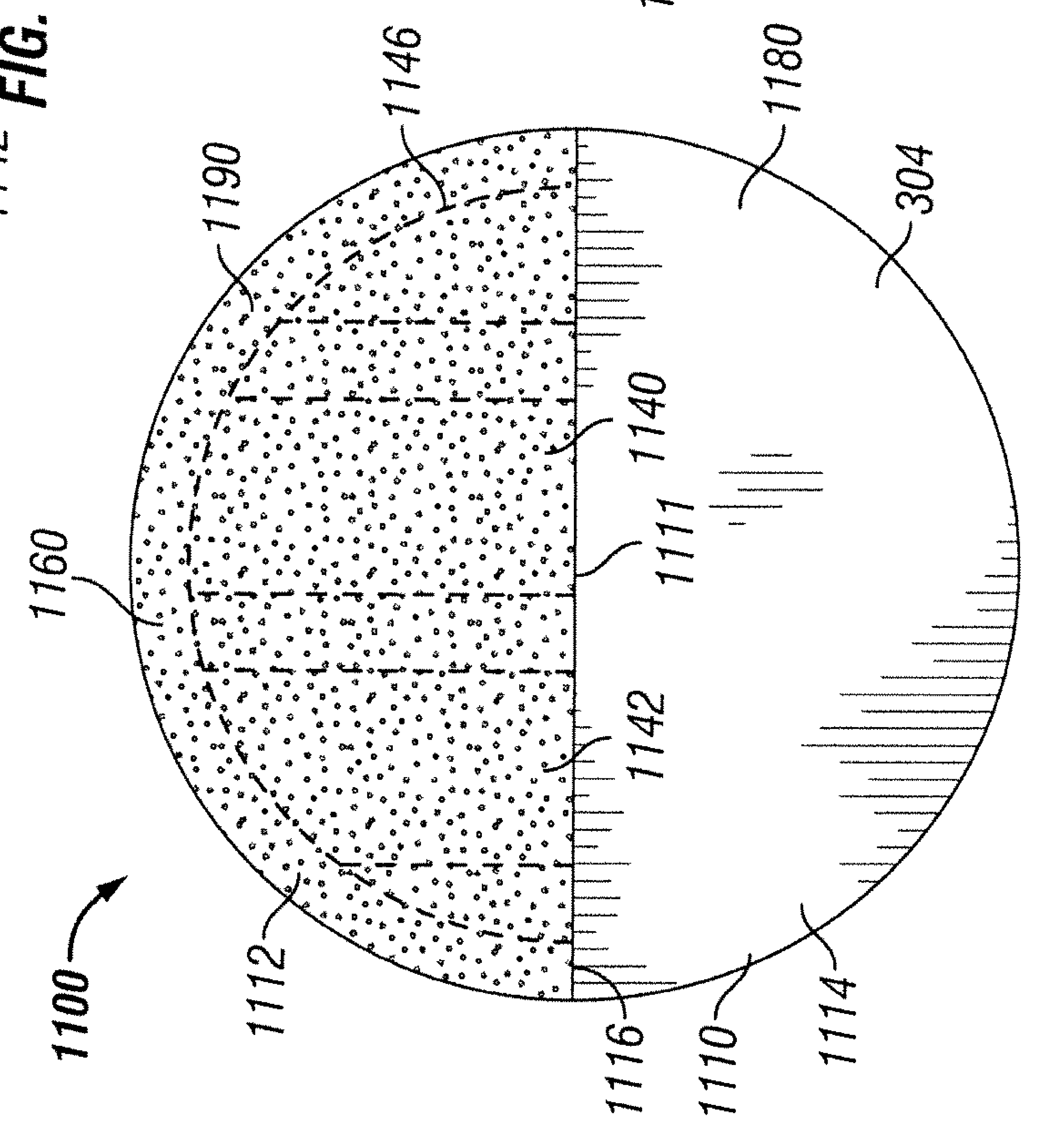


FIG. 11B

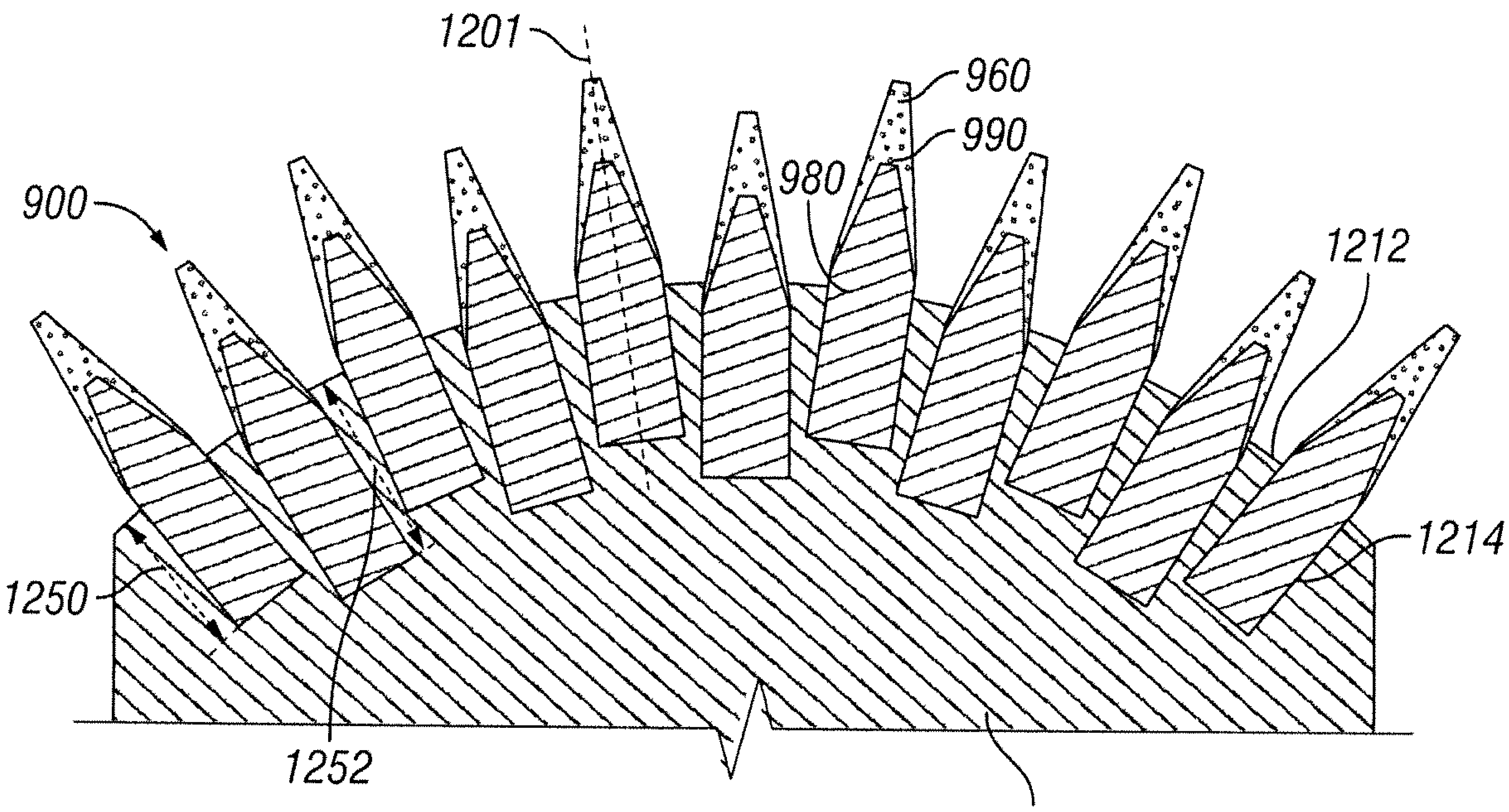

1201
960
990
980
900
1212
1214
1250
1252
1210

FIG. 12

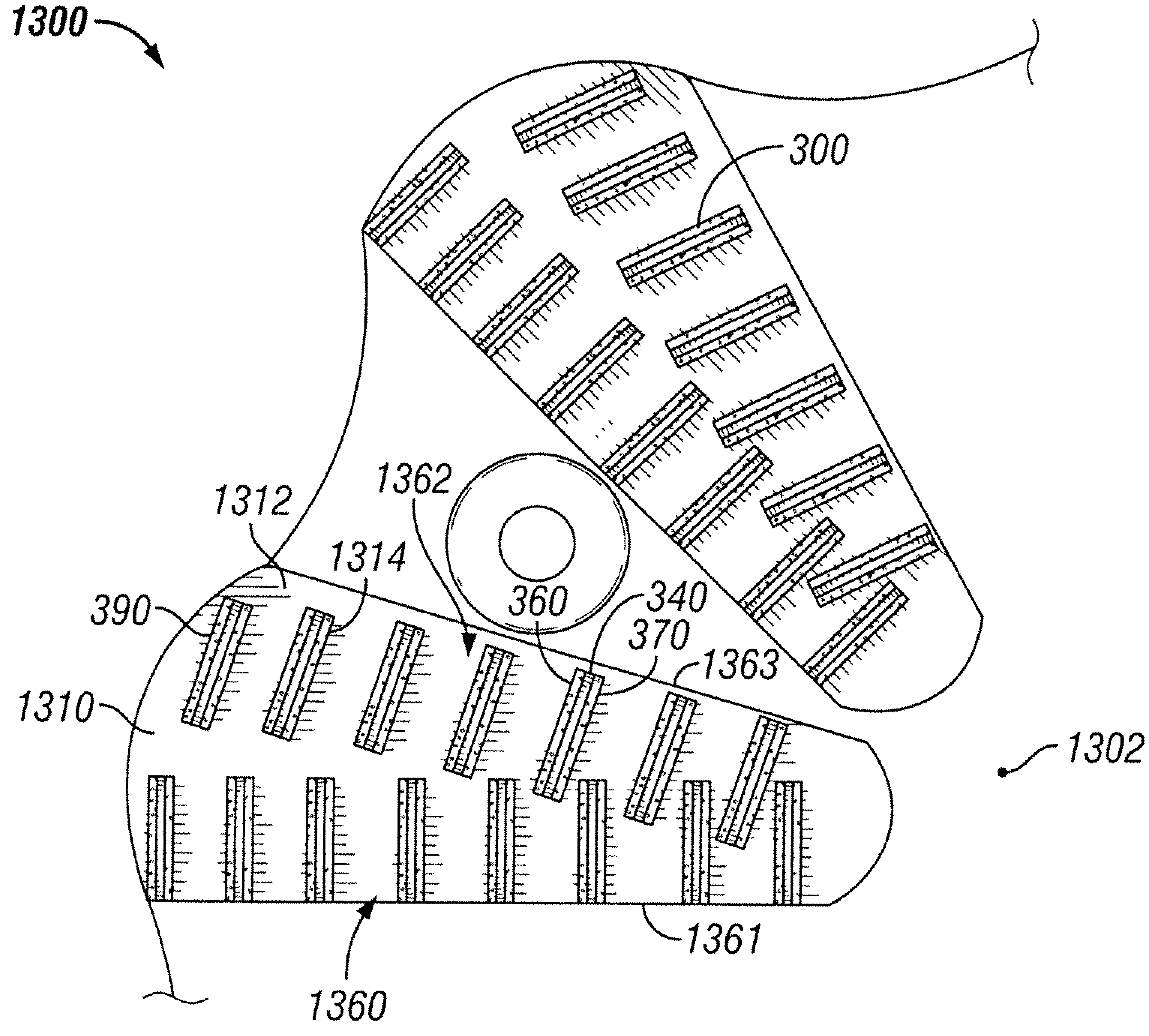

1300
300
1362
1312
1314
390
360
340
370
1363
1310
1302
1361
1360

FIG. 13

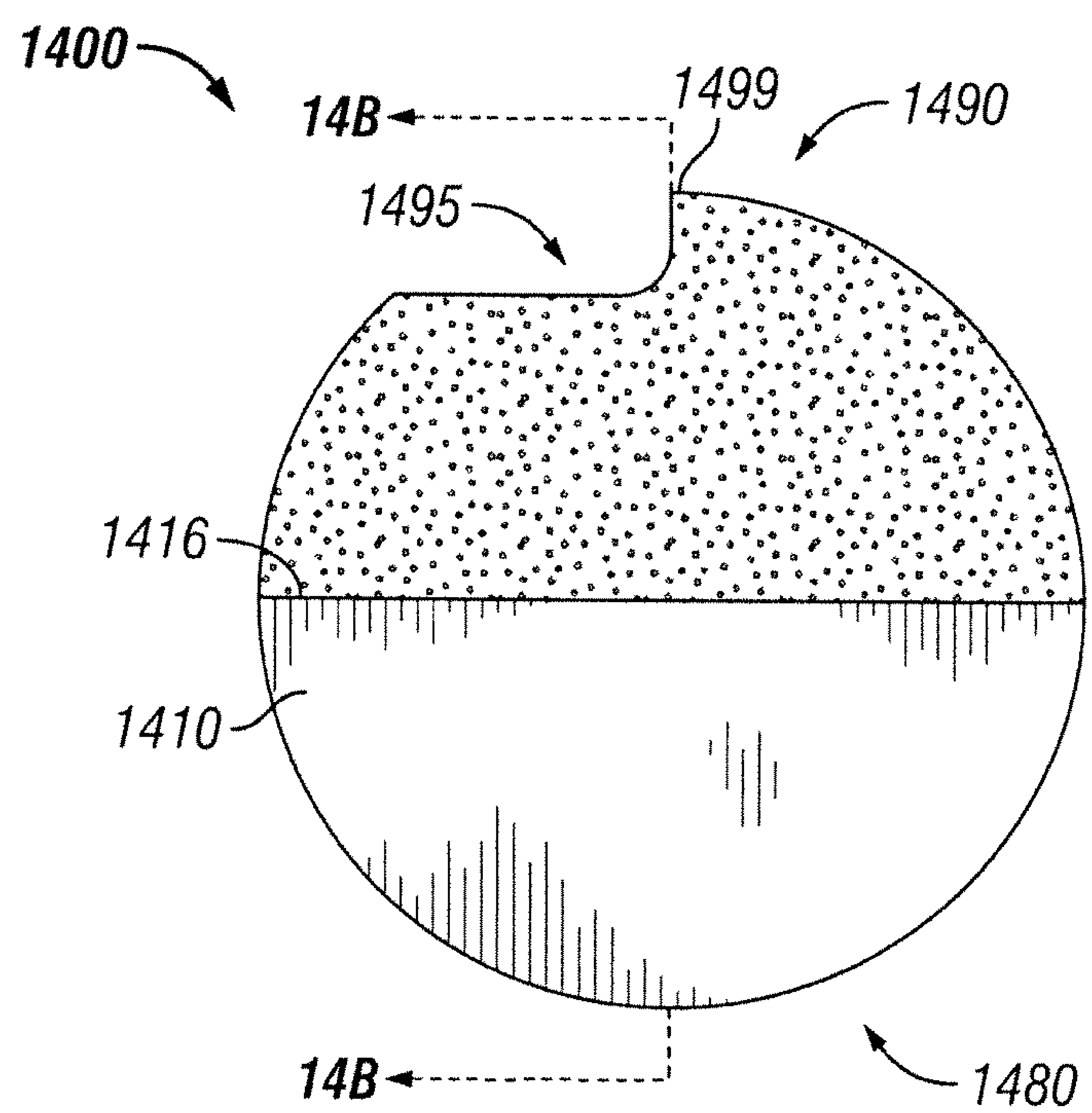


FIG. 14A

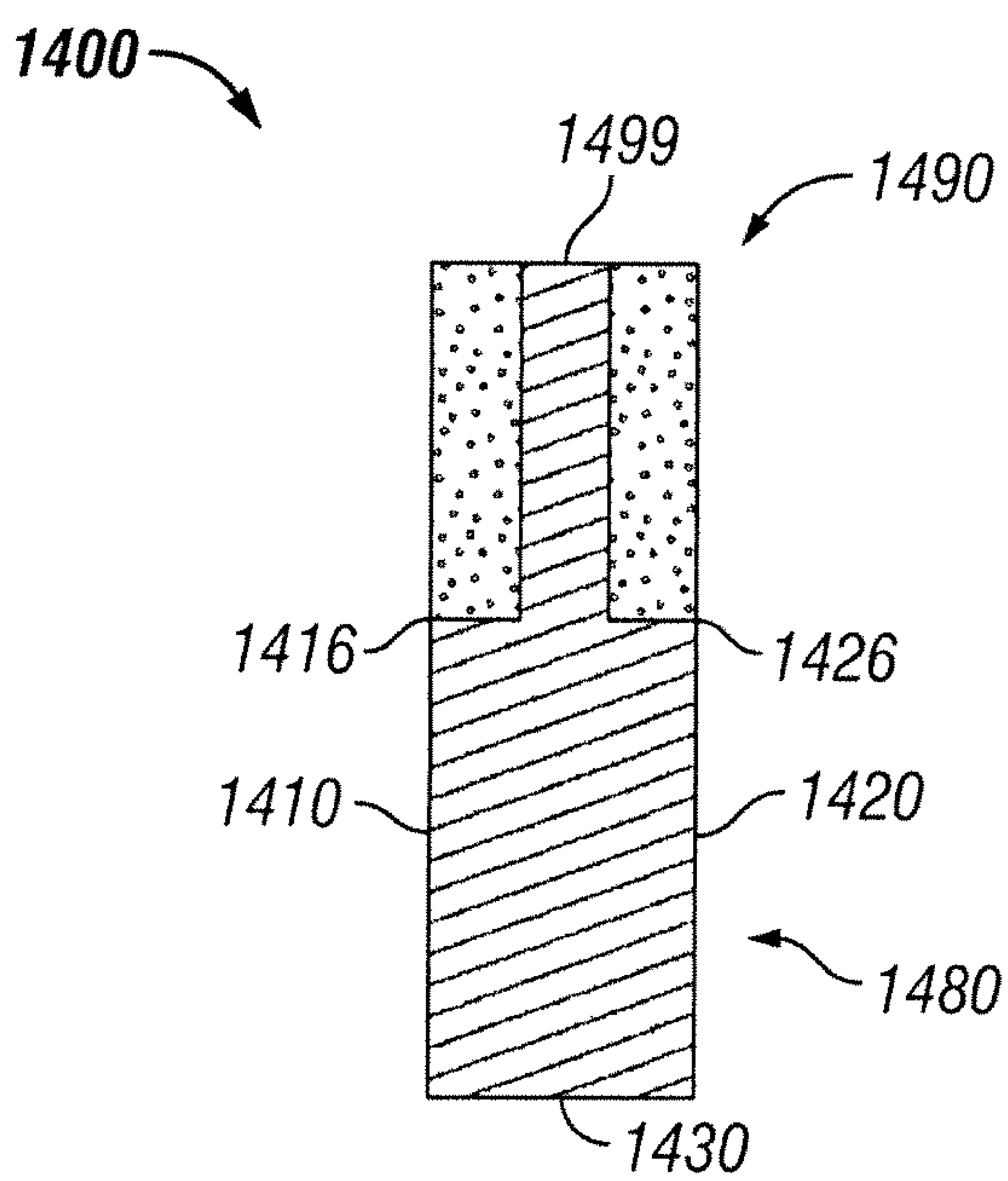


FIG. 14B

PDC DISC CUTTERS AND ROTARY DRILL BITS UTILIZING PDC DISC CUTTERS

RELATED APPLICATION

This application claims priority to U.S. application Ser. No. 61/507,503, entitled "PDC Disc Cutters And Rotary Drill Bits Utilizing PDC Disc Cutters," filed Jul. 13, 2011, which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present invention relates generally to downhole tools used in drilling a wellbore; and more particularly, to disc cutters and downhole tools, such as rotary drill bits, using one or more disc cutters therein.

BACKGROUND

Disc bits and other downhole tools that use disc cutters for rock formation drilling are known to persons having ordinary skill in the art. These known disc bits range from having two or three large disc cutters, which are aimed to compete with the three-cone type roller cone bits, to having many smaller rolling disc assemblies on the face of the bit.

FIG. **1** is an elevational view of a conventional disc bit **100** in accordance with one example of the prior art. The conventional disc bit **100** includes a sub **110**, a first blade **120**, and a second blade **130**. The sub **110** includes an upper threaded end **112** at one end and a lower bifurcated pivotal end **114** at the opposing end. The sub **110** is in the form of a hollow cylindrical body, but can be shaped differently in other embodiments. The first blade **120** is pivotally coupled to the lower bifurcated pivotal end **114** and is shown in a cutting position **105**, which is oriented substantially perpendicular to the length of the sub **110**. Similarly, the second blade **130** is pivotally coupled to the lower bifurcated pivotal end **114** and also is shown in the cutting position **105**, which is oriented substantially perpendicular to the length of the sub **110** and substantially opposite of the first blade **120**. When the first and second blades **120**, **130** are positioned in a non-cutting position (not shown), the blades **120**, **130** are positioned substantially axially to the sub **110** and positioned substantially below the lower bifurcated pivotal end **114**. The blades **120**, **130** are pivoted around a portion of the lower bifurcated pivotal end **114** to move one or more of the blades **120**, **130** between the cutting position **105** and the non-cutting position.

Each of the blades **120**, **130** includes radially offset larger and smaller semi-circular body portions **141**, **146**. The larger body portion **141** is positioned adjacent the lower bifurcated pivotal end **114**, while the smaller body portion **146** extends from the end of the larger body portion **141** to a distance further away from the lower bifurcated pivotal end **114**. The smaller body portion **146** includes one or more first cutters **147**, each of which are positioned within a corresponding recess **148** formed within the undersurface, or a leading edge **122**, of each blade **120**, **130**. The first cutters **147** are mounted into the recesses **148** using an axle (not shown) extending through the first cutter **147**. The first cutters **147** are disk-shaped and are typically uniformly fabricated from tungsten carbide. Each first cutter **147** includes a tapered surface **149** formed radially around the circumference of the first cutter **147**. This tapered surface **149** forms a cutting edge **150** for the first cutter **147**. The larger body portion **141** includes one or more second cutters **142**, each of which are positioned within a corresponding recess **143** formed within the undersurface, or the leading edge **122**, of each blade **120**, **130**. The second cutters **142** are mounted into the recesses **143** using an axle (not shown) extending through the second cutter **142**. The second cutters **142** are disk-shaped and are typically uniformly fabricated from tungsten carbide. Each second cutter **142** includes a tapered surface **144** formed radially around the circumference of the second cutter **142**. This tapered surface **144** forms a cutting edge **145** for the second cutter **142**. Each of the blades **120**, **130** also includes one or more cutting inserts **155**, typically formed from tungsten carbide, coupled within a corresponding circular recess **156** formed along a trailing edge **124** of each blade **120**, **130**. Each insert **155** is of a generally elongated cylindrical configuration which protrudes from the trailing edge **124** in order to cut into the formation when the blades **120**, **130** are rotated. The cutting inserts **155** are most useful in the event of formation hole collapse, hole sloughing or hole swelling. In operation, the first and second cutters **142**, **147** freely rotate around the axle so that a fresh corresponding tapered surface **144**, **149** is exposable for cutting the rock formation.

FIG. **2** is a perspective view of a conventional disc bit **200** or head of a conventional shaft in accordance with another example of the prior art. The head **200** includes a generally circular bit body **205**, which is adapted to be coupled to a drilling or tunneling machine (not shown) to be rotated and pushed or pulled through a rock or earthen formation to form a wellbore.

A plurality of saddle members **220** are secured to the bit body **205** at various selected locations. A cutter shell or sleeve **230** is carried for rotation by a journal member (not shown), an end of which is secured to and supported by the saddle member **220**. Methods of securing journal members to saddle members **220** are known to persons having ordinary skill in the art. A plurality of disc-type cutters **250** are coupled to the face of the bit body **205** using the saddle members **220**. The disc-type cutters **250** include a raised, annular kerf ring **255** and are releasably secured to each cutter sleeve or shell **230**. As the bit body **205** is rotated and pushed or pulled through the formation, the cutters **250** and the kerf rings **255** engage the formation, scoring it in generally circular patterns and causing the fracture of large cuttings or fragments of rock from the formation. The cuttings (not shown) removed by disc-type cutters **250** are removed with less energy per volume of rock fractured and produce larger cuttings, which are easier to remove from the wellbore as boring progresses.

Currently disc bits are at best used in only an extremely small segment of the overall market for oilfield or blast hole mining drilling. Disc cutters are quite successful though in large diameter tunneling, or raise boring, machines. The historical failure of disc cutters in oilfield applications has been their reliance on relative small diameter axles running through the center of steel or tungsten carbide rolling disc cutters. The axles are prone to breakage from weight-on-bit and rapid wear in the abrasive drilling environment. If the axle and/or the disc interface with the axle is lubricated and sealed, then each disc assembly requires a lubrication and compensation system (not shown) which rapidly consumes the available "real estate" in the bit body. In addition, the steel disc cutters, and even those made of tungsten carbide, are prone to rapid wear of the cutting edge.

In spite of all of the above drawbacks, disc bits continue to attract attention because they offer an entirely different rock failure mechanism than the crushing/scraping of conventional roller cone bits or the shear cutting of conventional PDC bits. Disc bits allow for high point loading on the cutters and fail the rock through a slicing/plowing/spalling mechanism. In many formations, this cutting mechanism can produce very high rates of penetration at relatively low torque levels.

What is needed is a disc cutter and bit design approach that offers the advantages of the high point loading slicing/plowing/spalling available from disc cutters while overcoming the small axle and/or the rapid disc wear drawbacks of disc bits previously in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and aspects of the invention are best understood with reference to the following description of certain exemplary embodiments, when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an elevational view of a conventional disc bit in accordance with one example of the prior art;

FIG. **2** is a perspective view of a conventional disc bit or head of a conventional shaft in accordance with another example of the prior art;

FIG. **3**A is a front view of a polycrystalline diamond compact ("PDC") disc cutter in accordance with an exemplary embodiment of the present invention;

FIG. **3**B is a side cross-sectional view of the PDC disc cutter of FIG. **3**A;

FIG. **4**A is a front view of a PDC disc cutter in accordance with another exemplary embodiment of the present invention;

FIG. **4**B is a side cross-sectional view of the PDC disc cutter of FIG. **4**A;

FIG. **5**A is a side cross-sectional view of a portion of a blade on a disc bit illustrating the PDC disc cutters of FIGS. **4**A and **4**B mounted therein in accordance with an exemplary embodiment of the present invention;

FIG. **5**B is a top view of two consecutive blades on a portion of the disc bit of FIG. **5**A in accordance with an exemplary embodiment of the present invention;

FIG. **6**A is a front view of a PDC disc cutter in accordance with a third exemplary embodiment of the present invention;

FIG. **6**B is a side cross-sectional view of the PDC disc cutter of FIG. **6**A;

FIG. **7** is a side cross-sectional view of a portion of a blade on a disc bit illustrating the PDC disc cutters of FIGS. **6**A and **6**B mounted therein in accordance with an exemplary embodiment of the present invention;

FIG. **8**A is a front view of the PDC disc cutter of FIGS. **6**A and **6**B mounted into a matrix pocket formed within a blade of a disc bit in accordance with another exemplary embodiment of the present invention;

FIG. **8**B is a side cross-sectional view of the PDC disc cutter of FIGS. **6**A and **6**B mounted into the matrix pocket of FIG. **8**A;

FIG. **9**A is a front view of a PDC disc cutter in accordance with a fourth exemplary embodiment of the present invention;

FIG. **9**B is a side cross-sectional view of the PDC disc cutter of FIG. **9**A;

FIG. **10**A is a front view of a PDC disc cutter in accordance with a fifth exemplary embodiment of the present invention;

FIG. **10**B is a side cross-sectional view of the PDC disc cutter of FIG. **10**A;

FIG. **11**A is a top view of a PDC disc cutter in accordance with a sixth exemplary embodiment of the present invention;

FIG. **11**B is a side view of the PDC disc cutter of FIG. **11**A;

FIG. **11**C is a perspective view of the PDC disc cutter of FIG. **11**A;

FIG. **12** is a side cross-sectional view of a portion of a blade on a disc bit illustrating the PDC disc cutters of FIGS. **9**A and **9**B mounted therein in accordance with an exemplary embodiment of the present invention;

FIG. **13** is a top view of two consecutive blades on a portion of a disc bit illustrating the PDC disc cutters of FIGS. **3**A and **3**B mounted therein in accordance with an exemplary embodiment of the present invention;

FIG. **14**A is a front view of a PDC disc cutter in accordance with an exemplary embodiment of the present invention; and

FIG. **14**B is a side cross-sectional view of the PDC disc cutter of FIG. **14**A in accordance with an exemplary embodiment of the present invention.

The drawings illustrate only exemplary embodiments of the invention and are therefore not to be considered limiting of its scope, as the invention may admit to other equally effective embodiments.

BRIEF DESCRIPTION OF EXEMPLARY EMBODIMENTS

The present invention is directed generally to downhole tools used in drilling a wellbore; and more particularly, to disc cutters and downhole tools, such as rotary drill bits, using one or more disc cutters therein. Although the description of exemplary embodiments is provided below in conjunction with a PDC disc cutter, alternate embodiments of the invention may be applicable to other types of disc cutters and tools using disc cutters including, but not limited to, PCBN disc cutters.

In certain exemplary embodiments, the disc cutters are fabricated having polycrystalline diamond, or some other superhard material such as cubic boron nitride, being pressed onto the sides, and in some cases over the cutting edge, of a substrate disc. The substrate disc is fabricated from tungsten carbide or some other suitable material.

FIG. **3**A is a front view of a polycrystalline diamond compact ("PDC") disc cutter **300** in accordance with an exemplary embodiment of the present invention. FIG. **3**B is a side cross-sectional view of the PDC disc cutter **300**. Referring to FIGS. **3**A and **3**B, the PDC disc cutter **300** is cylindrically shaped, or disc-shaped, and includes a first surface **310**, a second surface **320**, and a sidewall **330** extending from the first surface **310** to the second surface **320**.

The first surface **310** is substantially planar and includes a first top portion **312**, a first bottom portion **314**, and a first interface **316** positioned between the first top portion **312** and the first bottom portion **314**. However, the first surface **310** is non-planar in certain exemplary embodiments. In certain exemplary embodiments, the first interface **316** is a diameter of the first surface **310** and forms about a 180 degree angle from a first centerpoint **311** of the first surface **310**. However, in other exemplary embodiments, the first interface **316** forms an angle that is either greater than 180 degrees or less than 180 degrees from the first centerpoint **311**. Additionally, the first interface **316** is not a diameter of the first surface **310** in certain exemplary embodiments.

Similarly, the second surface **320** is substantially planar and includes a second top portion **322**, a second bottom portion **324**, and a second interface **326** positioned between the second top portion **322** and the second bottom portion **324**. However, the second surface **320** is non-planar in certain exemplary embodiments. In certain exemplary embodiments, the second interface **326** is a diameter of the second surface **320** and forms about a 180 degree angle from a second centerpoint (not shown) of the second surface **320**. However, in other exemplary embodiments, the second interface **326** forms an angle that is either greater than 180 degrees or less than 180 degrees from the second centerpoint. Additionally, the second interface **326** is not a diameter of the second surface **320** in certain exemplary embodiments. In certain exemplary embodiments, the second interface **326** is similarly oriented, shaped, and positioned as the first interface **316** and also is aligned with the first interface **316**. Thus, the second bottom portion **324** is aligned with the first bottom portion **314** and the second top portion **322** is aligned with the first top portion **312**. However, in other exemplary embodiments, the second interface **326** is oriented, shaped, and/or positioned differently than the first interface **316**.

In certain exemplary embodiments, the first bottom portion **314** and the second bottom portion **324** are fabricated using a substrate material **304** that extends therebetween to form a lower portion **380** of the PDC disc cutter **300**. An intermediate substrate layer **340** extends outwardly from an intermediate depth **382** of the lower portion **380** into an upper portion **390** of the PDC disc cutter **300**. The intermediate substrate layer **340** also is fabricated using the substrate material **304** and is of a uniform thickness, according to some exemplary embodiments. In certain exemplary embodiments, the intermediate substrate layer **340** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. The intermediate substrate layer **340** includes a first side surface **342** and a second side surface **344**. The first side surface **342** faces in the direction of the first surface **310**, while the second side surface **344** faces in the direction of the second surface **320**. The first side surface **342** extends outwardly from the lower portion **380** at a first transition area **343**, while the second side surface **344** extends outwardly from the lower portion **380** at a second transition area **345**. According to some exemplary embodiments, the first transition area **343** is about a ninety degree angle; however, this first transition area **343** is less than a ninety degree angle, greater than a ninety degree angle, has a concave-shaped curvature, has a convex-shaped curvature, or has some combination of the previously mentioned transition area types in other exemplary embodiments. Similarly, according to some exemplary embodiments, the second transition area **345** is about a ninety degree angle; however, this second transition area **345** is less than a ninety degree angle, greater than a ninety degree angle, has a concave-shaped curvature, has a convex-shaped curvature, or has some combination of the previously mentioned transition area types in other exemplary embodiments.

The substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. The cobalt behaves as a binder material for the tungsten carbide and facilitates formation of the tungsten carbide substrate when exposed to high pressure high temperature ("HPHT") conditions. In certain exemplary embodiments, high cobalt content is used within the substrate material **304** to accommodate side torque stresses on the PDC disc cutters **300** as they wear. Although tungsten carbide and cobalt powders have been provided as example materials for forming the substrate material **304**, other materials known to people having ordinary skill in the art, such as a different binder material, can be used to form this substrate material **304**. For example, the substrate material **304** is fabricated using a different binder material, such as a molybdenum binder or a nickel binder, in lieu of the cobalt binder. In another example, the substrate material **304** is fabricated using a different carbide, such as a titanium carbide or a molybdenum carbide, in lieu of the tungsten carbide. The substrate material **304** is manufactured using standard sintering techniques, or other techniques, such as microwave sintering.

A first cutting table **360** extends from the first side surface **342** to the first top portion **312**. In certain exemplary embodiments, the first cutting table **360** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. In certain exemplary embodiments, the first cutting table **360** is a polycrystalline diamond table which is formed from diamond powder and cobalt, which may be infiltrated from the mixture of tungsten carbide and cobalt powders used to form the substrate material **304** during HPHT conditions, which can be in either a HPHT press or in a ultra HPHT press. The cobalt behaves as a catalyst material for sintering the diamond powder to form diamond-diamond bonds. The diffusion of cobalt into the diamond powder results in cobalt being deposited within the voids formed within the first cutting table **360**. However, according to certain exemplary embodiments, at least a portion of this deposited cobalt is removed from the voids, thereby creating a thermally stable first cutting table **360**. Depending upon the exemplary embodiment, the cobalt is completely removed, partially removed, removed in patterns, or randomly removed from the first cutting table **360**. Some processes used to remove this cobalt includes, but is not limited to, acid leaching, electrolysis removal, and other known processes. Thus, the superhard material layer that forms the first cutting table **360** can be rich in catalyst material, such as cobalt, average in catalyst material, or lean in catalyst material depending upon design choices. Although diamond powder and cobalt have been provided as example materials for forming the first cutting table **360**, other materials known to people having ordinary skill in the art, such as cubic boron nitride and/or a different catalyst material, can be used to form this first cutting table **360**. For example, in certain exemplary embodiments, the first cutting table **360** is fabricated using other superhard materials, such as impregnated diamond matrix or cubic boron nitride. If the first cutting table **360** is made from diamond, the polycrystalline diamond feedstock can be of natural diamond or synthetic diamond. The grain size of the diamond feedstock is one of fine gained, medium gained, large grained, or a combination of different grain sizes. If the first cutting table **360** is made from impregnated diamond matrix, the diamond grains may be of natural diamond or synthetic diamond. The superhard material layer of an impregnated diamond disc may be applied in a standard furnace, a microwave furnace, a hot isostatic press, or any other know furnaces and/or presses. If the first cutting table **360** is made from impregnated diamond matrix, the diamond grains may be of natural diamond or synthetic diamond. According to certain exemplary embodiments, the superhard material layer that forms the cutting table **360** is between about 0.010 inches and about 0.125 inches; however, this thickness is greater or smaller in other exemplary embodiments.

Additionally, the superhard material layer of the first cutting table **360** may be of a transitional nature wherein the diamond content of the outer layer of the superhard material has a higher concentration of diamond and an inner layer or layers have a lower concentration of diamond. This transition in diamond content from the outer layers to the inner layers is progressive in some exemplary embodiments, while the transition is step-wise in other exemplary embodiments. Further, the superhard material layer of the first cutting table **360** may include zones of thermally stable polycrystalline diamond. Moreover, the superhard material layer may have serrations, holes, grooves, or other features to enhance cleaning, cooling, cutter aggressiveness, or cutter durability.

A second cutting table **370** extends from the second side surface **344** to the second top portion **322**. In certain exemplary embodiments, the second cutting table **370** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. The second cutting table **370** is formed similarly to any one of the examples provided above with respect to the first cutting table **360**. The first cutting table **360**, the intermediate substrate layer **340**, and the second cutting table **370** form the upper portion **390** of the PDC disc cutter **300**. In certain exemplary embodiments, however, a portion of the intermediate substrate layer **340** is replaced with either the first cutting table **360** or the second cutting table **370** without departing from the scope and spirit of the exemplary embodiments. Additionally, in certain exemplary embodiments, the first cutting table **360** is fabricated from one or more different materials than the second cutting table **370**.

FIG. **4**A is a front view of a PDC disc cutter **400** in accordance with another exemplary embodiment of the present invention. FIG. **4**B is a side cross-sectional view of the PDC disc cutter **400**. Referring to FIGS. **4**A and **4**B, the PDC disc cutter **400** is cylindrically shaped, or disc-shaped, and includes a first surface **310**, a second surface **320**, and a sidewall **330** extending from the first surface **310** to the second surface **320**.

The first surface **310** is substantially planar and includes a first top portion **312**, a first bottom portion **314**, and a first interface **316** positioned between the first top portion **312** and the first bottom portion **314**. However, the first surface **310** is non-planar in certain exemplary embodiments. In certain exemplary embodiments, the first interface **316** is a diameter of the first surface **310** and forms about a 180 degree angle from a first centerpoint **311** of the first surface **310**. However, in other exemplary embodiments, the first interface **316** forms an angle that is either greater than 180 degrees or less than 180 degrees from the first centerpoint **311**. Additionally, the first interface **316** is not a diameter of the first surface **310** in certain exemplary embodiments.

Similarly, the second surface **320** is substantially planar and includes a second top portion **322**, a second bottom portion **324**, and a second interface **326** positioned between the second top portion **322** and the second bottom portion **324**. However, the second surface **320** is non-planar in certain exemplary embodiments. In certain exemplary embodiments, the second interface **326** is a diameter of the second surface **320** and forms about a 180 degree angle from a second centerpoint (not shown) of the second surface **320**. However, in other exemplary embodiments, the second interface **326** forms an angle that is either greater than 180 degrees or less than 180 degrees from the second centerpoint. Additionally, the second interface **326** is not a diameter of the second surface **320** in certain exemplary embodiments. In certain exemplary embodiments, the second interface **326** is similarly oriented, shaped, and positioned as the first interface **316** and also is aligned with the first interface **316**. Thus, the second bottom portion **324** is aligned with the first bottom portion **314** and the second top portion **322** is aligned with the first top portion **312**. However, in other exemplary embodiments, the second interface **326** is oriented, shaped, and/or positioned differently than the first interface **316**.

In certain exemplary embodiments, the first bottom portion **314** and the second bottom portion **324** are fabricated using a substrate material **304** that extends therebetween to form a lower portion **380** of the PDC disc cutter **400**. An intermediate substrate layer **340** extends outwardly from an intermediate depth **382** of the lower portion **380** into an upper portion **390** of the PDC disc cutter **400**. The intermediate substrate layer **340** also is fabricated using the substrate material **304** and is of a uniform thickness, according to some exemplary embodiments. In certain exemplary embodiments, the intermediate substrate layer **340** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. The intermediate substrate layer **340** includes a first side surface **342** and a second side surface **344**. The first side surface **342** faces in the direction of the first surface **310**, while the second side surface **344** faces in the direction of the second surface **320**. The first side surface **342** extends outwardly from the lower portion **380** at a first transition area **443**, while the second side surface **344** extends outwardly from the lower portion **380** at a second transition area **445**. According to some exemplary embodiments, the first transition area **443** has a concave-shaped curvature. Similarly, according to some exemplary embodiments, the second transition area **445** has a concave-shaped curvature. The first transition area **443** transitions from the first interface **316** to the first side surface **342**, while the second transition area **445** transitions from the second interface **326** to the second side surface **344**.

The substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. However, the substrate material **304** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A first cutting table **360** extends from the first side surface **342** to the first top portion **312**. In certain exemplary embodiments, the first cutting table **360** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. The cutting table **360** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A second cutting table **370** extends from the second side surface **344** to the second top portion **322**. In certain exemplary embodiments, the second cutting table **370** is half disc-shaped and forms a circumferential portion of the sidewall **330** located in the upper portion **390**. The second cutting table **370** is formed similarly to any one of the examples provided above with respect to the first cutting table **360**. The first cutting table **360**, the intermediate substrate layer **340**, and the second cutting table **370** form the upper portion **390** of the PDC disc cutter **300**. In certain exemplary embodiments, however, a portion of the intermediate substrate layer **340** is replaced with either the first cutting table **360** or the second cutting table **370** without departing from the scope and spirit of the exemplary embodiments. Additionally, in certain exemplary embodiments, the first cutting table **360** is fabricated from one or more different materials than the second cutting table **370**.

FIG. **5**A is a side cross-sectional view of a portion of a blade **510** on a disc bit **500** illustrating the PDC disc cutters **400** mounted therein in accordance with an exemplary embodiment of the present invention. FIG. **5**B is a top view of two consecutive blades **510** on a portion of the disc bit **500** in accordance with an exemplary embodiment of the present invention. Referring to FIGS. **5**A and **5**B, the disc bit **500** includes a plurality of blades **510** extending outwardly from a disc bit centerline **502**. Each blade **510** includes at least one PDC disc cutter **400** mounted thereto via gluing or brazing. If the PDC disc cutter **400** is brazed onto the blade **510**, the brazing is performed using torch brazing or furnace brazing. The disc bit **500** is made from tungsten carbide matrix, but can be made from steel, tungsten matrix, titanium matrix, or some other suitable material.

Each blade **510** includes a mounting surface **512** which generally faces a portion of the wellbore (not shown) once disposed within the wellbore. The mounting surface **512** generally has a convex-shaped curvature that includes one or more cavities **514** formed therein. The cavities **514** are formed during the molding process in forming the blade **510**. Alternatively, the blade **510** is formed and thereafter the cavities **514** are formed therein via drilling or some other known method. Alternatively, the cavities **514** are formed using other methods known to persons having ordinary skill in the art. Each cavity **514** is configured to receive a portion of a corresponding PDC disc cutter **400** via brazing or any other known method. Thus, one or more of the PDC disc cutters **400** are fixedly coupled to the blade **510**. At least a portion of the lower portion **380** of each PDC disc cutter **400** is coupled within the corresponding cavity **514**, while at least a portion of the upper portion **390** of each PDC disc cutter **400** is exposed beyond the mounting surface **512**. Thus, the first cutting table **360**, the second cutting table **370**, and an edge of the intermediate substrate layer **340** are exposed to cut into the wellbore during drilling.

The PDC disc cutters **400** are aligned one after another and are inserted substantially the same depth into each of the corresponding cavities **514**. However, one or more of the PDC disc cutters **400** are inserted substantially at a different depth into the corresponding cavity **514** than at least one other PDC disc cutter **400**, thereby providing for different cutter exposure levels. For example, alternating PDC disc cutters **400** are inserted at a first depth, while intervening PDC disc cutters **400**, wherein a single intervening PDC disc cutter **400** is positioned between two alternating disc cutters **400**, are inserted at a second depth. According to some exemplary embodiments, a central axis **501** of one or more of the PDC disc cutters **400** is oriented substantially perpendicular to the mounting surface **512**. However, in other exemplary embodiments, the central axis **501** of one or more PDC disc cutters **400** is oriented non-perpendicularly to the mounting surface **512**. In some exemplary embodiments, one or more PDC disc cutters **400** are a different size than at least one other PDC disc cutter **400**. For example, in certain exemplary embodiments, the smaller PDC disc cutters **400** are coupled into the blade **510** closer to the disc bit centerline **502**, while the larger PDC disc cutters **400** are coupled within the blade **510** further away from the disc bit centerline **502**. At times, this configuration is determinable by the shape and available surface area of the blade **510** as it extends away form the disc bit centerline **502**. Also, according to some exemplary embodiments, the PDC disc cutters **400** are deployed on a disc bit **500** in a stepwise manner. For example, the disc bit **500** can have a frustoconical shape with concentric platforms at progressively higher elevations going from the outer perimeter of the disc bit **500** towards the disc bit centerline **502**. One or more PDC disc cutters **400** are deployed on each differently elevated concentric platform in a concentric manner. Although some different profiles have been described with respect to the bit **500**, the bit **500** can be of many other profile types including, but not limited to, flat profile, shallow parabolic profile, long parabolic profile, and intermediate parabolic profile.

Additionally, one or more of the PDC disc cutters **400** are slightly side raked to reduce side loading stresses on a trailing edge of the PDC disc cutters **400**. Side raking, which is the angling of the back portion of the PDC disc cutter **400** towards the central axis **501**, facilitates the PDC disc cutters **400** to track better in the circumferential cut made by a leading portion of the PDC disc cutter **400**. This side rake angle is between one degree and eighty-nine degrees depending upon the exemplary embodiment. In other exemplary embodiments, the side rake angle is greater or less than the aforementioned angles.

Further, according to some exemplary embodiments, one or more of the blades **510** of the disc bit **500** includes more than one row of disc cutters **400**. In certain exemplary embodiments, the disc bit **500** utilizes a combination of disc cutters **400** and shear cutters (not shown), which are known in the art. For example, one blade **510** includes alternating disc cutters **400** and shear cutters in a row. In another example, the shear cutters are positioned at bit center, while the disc cutters **400** are positioned at the nose of the bit **500** and/or at the shoulder of the bit **500**. In a further example, the shear cutters are positioned at the gage of the bit **500**, while the disc cutters **400** are positioned at the nose of the bit **500** and/or at the shoulder of the bit **500**. Alternatively, instead of being intermixed with regular shear cutters on a bit, the disc cutters **400** are intermixed with impregnated segments or impregnated posts.

FIG. **6**A is a front view of a PDC disc cutter **600** in accordance with a third exemplary embodiment of the present invention. FIG. **6**B is a side cross-sectional view of the PDC disc cutter **600**. Referring to FIGS. **6**A and **6**B, the PDC disc cutter **600** is cylindrically shaped, or disc-shaped, and includes a first surface **610**, a second surface **620**, and a sidewall **630** extending from the first surface **610** to the second surface **620**.

The first surface **610** includes a first top portion **612**, a first bottom portion **614**, and a first interface **616** positioned between the first top portion **612** and the first bottom portion **614**. In certain exemplary embodiments, the first interface **616** is a diameter of the first surface **610** and forms about a 180 degree angle from a first centerpoint **611** of the first surface **610**. However, in other exemplary embodiments, the first interface **616** forms an angle that is either greater than 180 degrees or less than 180 degrees from the first centerpoint **611**. Additionally, the first interface **616** is not a diameter of the first surface **610** in certain exemplary embodiments. The first top portion **612** includes a first groove **613** formed at a distal portion of the first top portion **612** near a portion of the sidewall **630**. The first groove **613** is arcuately shaped, but is shaped differently in other exemplary embodiments. The first top portion **612** is non-planar in that the portion near the sidewall **630** and is curve-shaped as it converges with the sidewall **630**. The first bottom portion **614** is substantially planar, but can be non-planar in certain exemplary embodiments.

Similarly, the second surface **620** includes a second top portion **622**, a second bottom portion **624**, and a second interface **626** positioned between the second top portion **622** and the second bottom portion **624**. In certain exemplary embodiments, the second interface **626** is a diameter of the second surface **620** and forms about a 180 degree angle from a second centerpoint (not shown) of the second surface **620**. However, in other exemplary embodiments, the second interface **626** forms an angle that is either greater than 180 degrees or less than 180 degrees from the second centerpoint. Additionally, the second interface **626** is not a diameter of the second surface **620** in certain exemplary embodiments. In certain exemplary embodiments, the second interface **626** is similarly oriented, shaped, and positioned as the first interface **616** and also is aligned with the first interface **616**. Thus, the second bottom portion **624** is aligned with the first bottom portion **614** and the second top portion **622** is aligned with the first top portion **612**. However, in other exemplary embodiments, the second interface **626** is oriented, shaped, and/or positioned differently than the first interface **616**. The second top portion **622** includes a second groove **623** formed at a distal portion of the second top portion **622** near a portion of the sidewall **630**. The second groove **623** is arcuately shaped, but is shaped differently in other exemplary embodiments. The second top portion **622** is non-planar in that the portion near the sidewall **630** and is curve-shaped as it converges with the sidewall **630**. The second bottom portion **624** is substantially planar, but can be non-planar in certain exemplary embodiments.

At least a portion of the sidewall **630** extending from the first top portion **612** to the second top portion **622** has a convex-shaped side profile **632**. However, in other exemplary embodiments, this portion of the sidewall **630** has a different side profile shape, such as planar or concave-shaped, without departing from the scope and spirit of the exemplary embodiments.

In certain exemplary embodiments, the first bottom portion **614** and the second bottom portion **624** are fabricated using a substrate material **304** that extends therebetween to form a lower portion **680** of the PDC disc cutter **600**. An intermediate substrate layer **640** extends outwardly from the lower portion **680** into an upper portion **690** of the PDC disc cutter **600**. According to certain exemplary embodiments, the intermediate substrate layer **640** extends a greater distance from the lower portion **680** near the center portion of the lower portion **680** than near its edges. In these exemplary embodiments, a distal end **646** of the intermediate substrate layer **640** is non-planar. The intermediate substrate layer **640** also is fabricated using the substrate material **304** and is of a non-uniform thickness, according to some exemplary embodiments. In certain exemplary embodiments, the intermediate substrate layer **640** is about half disc-shaped. The intermediate substrate layer **640** includes a first side surface **642** and a second side surface **644**. The first side surface **642** faces in the direction of the first surface **610**, while the second side surface **644** faces in the direction of the second surface **620**. The first side surface **642** extends inwardly into the PDC disc cutter **600** from the first interface **616** and continues to the distal end **646** of the intermediate substrate layer **640**, which is positioned in the upper portion **690** near the sidewall **630** in the upper portion **690**. The first side surface **642** has a substantially half-parabolic shape; however, this shape is different in other exemplary embodiments. Similarly, the second side surface **644** extends inwardly into the PDC disc cutter from the second interface **626** and continues to the distal end **646** of the intermediate substrate layer **640**. The second side surface **644** has a substantially half-parabolic shape; however, this shape is different in other exemplary embodiments. The distal end **646** is convexed-shaped in certain exemplary embodiments, but is differently shaped, such as being planar or being concave-shaped, in other exemplary embodiments.

As previously mentioned, the substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. This substrate material **304** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A cutting table **660** is formed in the upper portion **690** and extends from the first side surface **642** to the first top portion **612**, from the second side surface **644** to the second top portion **622**, and from the remaining portions of the intermediate substrate layer **640**, including the distal end **646**, to the sidewall **630** in the upper portion **690**; thereby forming a circumferential portion of the sidewall **630** located in the upper portion **690**. In certain exemplary embodiments, the cutting table **660** is formed similarly to the first cutting table **360** described with respect to FIG. **3**A and with respect to all of the described embodiments.

FIG. **7** is a side cross-sectional view of a portion of a blade **710** on a disc bit (not shown) illustrating the PDC disc cutters **600** mounted therein in accordance with an exemplary embodiment of the present invention. Referring to FIG. **7**, the disc bit includes one or more blades **710**, of which only one is illustrated, where each blade **710** includes at least one PDC disc cutter **600** mounted thereto.

Each blade **710** includes a mounting surface **712** which generally faces a portion of the wellbore (not shown) once disposed within the wellbore. The mounting surface **712** generally has a convex-shaped curvature that includes one or more cavities **714** formed therein. The cavities **714** are formed during the molding process in forming the blade **710**. Alternatively, the blade **710** is formed and thereafter the cavities **714** are formed therein via drilling or some other known method. Alternatively, the cavities **714** are formed using other methods known to persons having ordinary skill in the art. Each cavity **714** is configured to receive a portion of a corresponding PDC disc cutter **600** via brazing or any other known method. Thus, one or more of the PDC disc cutters **600** are fixedly coupled to the blade **710**. At least a portion of the lower portion **680** of each PDC disc cutter **600** is coupled within the corresponding cavity **714**, while at least a portion of the upper portion **690** of each PDC disc cutter **600** is exposed beyond the mounting surface **712**. Thus, the cutting table **660** is exposed to cut into the wellbore during drilling.

The PDC disc cutters **600** are aligned one after another and are inserted substantially the same depth into each of the corresponding cavities **714**. However, one or more of the PDC disc cutters **600** are inserted substantially at a different depth into the corresponding cavity **714** than at least one other PDC disc cutter **600** in other exemplary embodiments. For example, alternating PDC disc cutters **600** are inserted at a first depth, while intervening PDC disc cutters **600**, wherein one or more intervening PDC disc cutters **600** are positioned between two alternating disc cutters **600**, are inserted at a second depth. According to some exemplary embodiments, a central axis **701** one or more of the PDC disc cutters **600** is oriented substantially perpendicular to the mounting surface **712**. However, in other exemplary embodiments, the central axis **701** of one or more PDC disc cutters **600** is oriented non-perpendicularly to the mounting surface **712**. In some exemplary embodiments, one or more PDC disc cutters **600** are a different size than at least one other PDC disc cutter **600**.

FIG. **8**A is a front view of the PDC disc cutter **600** mounted into a matrix pocket **810** formed within a blade **805** of a disc bit (not shown) in accordance with another exemplary embodiment of the present invention. FIG. **8**B is a side cross-sectional view of the PDC disc cutter **600** mounted into the matrix pocket **810** of FIG. **8**A. Referring to FIGS. **8**A and **8**B, the blade **805** includes a cavity **807** formed therein. The cavity **807** is longitudinally shaped and configured to receive a portion of the PDC disc cutter **600** therein. The cavity **807** forms a first blade edge **808** adjacent to one longitudinal side of the cavity **807** and a second blade edge **809** adjacent to the opposing longitudinal side of the cavity **807**. The cavity **807** is formed according to any of the methods known to persons having ordinary skill in the art. The blade **805** is formed from a tungsten carbide material according to some exemplary embodiments, but is formed from steel or any other known suitable material in other exemplary embodiments.

The matrix pocket **810** includes a first support edge **812**, a second support edge **816**, and a rear support edge **820** extending from one end of the first support edge **812** to a corresponding end of the second support edge **816**. A portion of the first support edge **812** extends outwardly from a portion of the first blade edge **808** in an upwardly direction and has an arcuately-shaped profile along a distal end **813** of the first support edge **812**. This shape is different according to other exemplary embodiments. This portion of the first support edge **812** extends outwardly from a first intermediate area **814** along the first blade edge **808** to the end of the first blade edge **808**. Also, the first support edge **812** extends outwards a greater distance from the end of the first blade edge **808** than from the first intermediate area **814**.

Similarly, a portion of the second support edge **816** extends outwardly from a portion of the second blade edge **809** in an upwardly direction and has an arcuately-shaped profile along a distal end **817** of the second support edge **816**. Thus, a portion of the cavity **807** is disposed between the first support edge **812** and the second support edge **816**. This shape is different according to other exemplary embodiments. This portion of the second support edge **816** extends outwardly from a first intermediate area **818** along the second blade edge **809** to the end of the second blade edge **809** that is opposite and nearer to the end of the first blade edge **808**. Also, the second support edge **816** extends outwards a greater distance from the end of the second blade edge **809** than from the first intermediate area **818**. In certain exemplary embodiments, the second support edge **816** is a mirror-image of the first support edge **812**.

The rear support edge **820** extends from the end of the first support edge **812** and the end of the first blade edge **808** to the end of the second support edge **816** and the end of the second blade edge **809**. The rear support edge **820** has an arcuately-shaped profile at its ends and has a substantially planar profile at its upper portion between the first support edge **812** and the second support edge **816** according to certain exemplary embodiments; however, this shape is different in other exemplary embodiments.

The first support edge **812**, the second support edge **816**, and the rear support edge **820** are formed integrally as a single component. The matrix pocket **810** surrounds a portion of the longitudinal edges of the cavity **807** and one end of a latitudinal edge of the cavity **807**. The matrix pocket **810** is elevationally raised compared to the elevation of the blade **805**.

The matrix pocket **810** is fabricated from a similar material as the blade **805** and is used to provide support to the PDC disc cutter **600** once inserted and coupled within the cavity **807**. The matrix pocket **810** is formed on a portion of the blade **805**. In certain exemplary embodiments, the matrix pocket **810** is formed at the same time the blade **805** is formed and also is formed integrally with the blade **805** pursuant to methods known to persons having ordinary skill in the art and having the benefit of the present disclosure.

The PDC disc cutter **600** is inserted and coupled within the cavity **807** pursuant to coupling methods known to persons having ordinary skill in the art, such as brazing methods. The PDC disc cutter **600** is further supported, during cutting operations within the wellbore, by the matrix pocket **810**. Once inserted within the cavity **807**, a portion of the upper portion **690** is exposed for cutting, while a remaining portion of the upper portion **690** is concealed by the matrix pocket **810**. The PDC disc cutter **600** is fixedly attached within the cavity **807**. Alternatively, an axle (not shown) can be inserted through a rotatable disc cutter that is inserted into the cavity **807**. One end of the axle can be supported by the first support edge **812**, while an opposing end of the axle can be supported by the second support edge **816**. In this alternative exemplary embodiment, the rear support edge **820** is optional. Although PDC disc cutter **600** is shown as being used in conjunction with the matrix pocket **810**, any PDC disc cutter can be used with the matrix pocket **810**.

FIG. **9**A is a front view of a PDC disc cutter **900** in accordance with a fourth exemplary embodiment of the present invention. FIG. **9**B is a side cross-sectional view of the PDC disc cutter **900**. Referring to FIGS. **9**A and **9**B, the PDC disc cutter **900** is disc-shaped and includes a first surface **910**, a second surface **920**, and a sidewall **930**, having a non-uniform thickness, extending from the first surface **910** to the second surface **920**.

The first surface **910** includes a first top portion **912**, a first bottom portion **914**, and a first interface **916** positioned between the first top portion **912** and the first bottom portion **914**. In certain exemplary embodiments, the first interface **916** is a diameter of the first surface **910** and forms about a 180 degree angle from a first centerpoint **911** of the first surface **910**. However, in other exemplary embodiments, the first interface **916** forms an angle that is either greater than 180 degrees or less than 180 degrees from the first centerpoint **911**. Additionally, the first interface **916** is not a diameter of the first surface **910** in certain exemplary embodiments. The first bottom portion **914** is substantially planar, but can be non-planar in certain exemplary embodiments. The first top portion **912** also is substantially planar, but extends towards the second surface **920** as it extends away from the first interface **916**. Thus, the first top portion **912** is non-planar with respect to the first bottom portion **914**.

Similarly, the second surface **920** includes a second top portion **922**, a second bottom portion **924**, and a second interface **926** positioned between the second top portion **922** and the second bottom portion **924**. In certain exemplary embodiments, the second interface **926** is a diameter of the second surface **920** and forms about a 180 degree angle from a second centerpoint (not shown) of the second surface **920**. However, in other exemplary embodiments, the second interface **926** forms an angle that is either greater than 180 degrees or less than 180 degrees from the second centerpoint. Additionally, the second interface **926** is not a diameter of the second surface **920** in certain exemplary embodiments. In certain exemplary embodiments, the second interface **926** is similarly oriented, shaped, and positioned as the first interface **916** and also is aligned with the first interface **916**. Thus, the second bottom portion **924** is aligned with the first bottom portion **914** and the second top portion **922** is aligned with the first top portion **912**. However, in other exemplary embodiments, the second interface **926** is oriented, shaped, and/or positioned differently than the first interface **916**. The second bottom portion **924** is substantially planar, but can be non-planar in certain exemplary embodiments. The second bottom portion **924** is substantially parallel to the first bottom portion **914** in certain exemplary embodiments. The second top portion **922** also is substantially planar, but extends towards the first surface **910** as it extends away from the second interface **926**. Thus, the second top portion **922** is non-planar with respect to the second bottom portion **924**. Hence, from a side view, the first top portion **912** and the second top portion **922** form a substantially cone-shaped profile.

At least a portion of the sidewall **930** extending from the first top portion **912** to the second top portion **922** has a planar side profile **932**. However, in other exemplary embodiments, this portion of the sidewall **930** has a different side profile shape, such as convex-shaped or concave-shaped, without departing from the scope and spirit of the exemplary embodiments.

In certain exemplary embodiments, the first bottom portion **914** and the second bottom portion **924** are fabricated using a substrate material **304** that extends therebetween to form a lower portion **980** of the PDC disc cutter **900**. An intermediate substrate layer **940** extends outwardly from both the first interface **916** and the second interface **926** into an upper portion **990** of the PDC disc cutter **900**. According to certain exemplary embodiments, the intermediate substrate layer **940** extends a greater distance from the lower portion **980** near the center portion of the lower portion **980** than near its edges. In these exemplary embodiments, a distal end **946** of the intermediate substrate layer **940** is non-planar. The intermediate substrate layer **940** also is fabricated using the substrate material **304** and is of a non-uniform thickness, according to some exemplary embodiments. Thus, the thickness of the intermediate substrate layer **940** reduces as it extends further away from the lower portion **980**. In certain exemplary embodiments, the intermediate substrate layer **940** is about half disc-shaped. The intermediate substrate layer **940** includes a first side surface **942** and a second side surface **944**. The first side surface **942** faces in the direction of the first surface **910**, while the second side surface **944** faces in the direction of the second surface **920**. The first side surface **942** extends inwardly into the upper portion **990** of the PDC disc cutter **900** from the first interface **916** and continues to the distal end **946** of the intermediate substrate layer **940**, which is positioned in the upper portion **990** near the sidewall **930** in the upper portion **990**. The first side surface **942** is substantially planar; however, this shape is different in other exemplary embodiments. Similarly, the second side surface **944** extends inwardly into the upper portion **990** of the PDC disc cutter **900** from the second interface **926** and continues to the distal end **946** of the intermediate substrate layer **940**. The second side surface **944** is substantially planar; however, this shape is different in other exemplary embodiments. The distal end **946**, when viewed from a side cross-sectional view, is planar in certain exemplary embodiments, but is differently shaped, such as being convex-shaped or being concave-shaped, in other exemplary embodiments.

As previously mentioned, the substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. This substrate material **304** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A cutting table **960** is formed in the upper portion **990** and extends from the first side surface **942** to the first top portion **912**, from the second side surface **944** to the second top portion **922**, and from the remaining portions of the intermediate substrate layer **940**, including the distal end **946**, to the sidewall **930** in the upper portion **990**; thereby forming a circumferential portion of the sidewall **930** located in the upper portion **990**. The cutting table **960** is formed similarly to the first cutting table **360** (FIG. **3**A) along with any of its several embodiments described.

FIG. **10**A is a front view of a PDC disc cutter **1000** in accordance with a fifth exemplary embodiment of the present invention. FIG. **10**B is a side cross-sectional view of the PDC disc cutter **1000**. Referring to FIGS. **10**A and **10**B, the PDC disc cutter **1000** is annularly disc-shaped, and includes a first surface **1010**, a second surface **1020**, an outer sidewall **1030** extending from an outer perimeter of the first surface **1010** to an outer perimeter of the second surface **1020**, an inner sidewall **1035** extending from an inner perimeter of the first surface **1010** to an inner perimeter of the second surface **1020**, and channel **1039** extending from the first surface **1010** to the second surface **1020** and defined by the inner sidewall **1035**.

The first surface **1010** includes a first outer portion **1012**, a first inner portion **1014**, and a first interface **1016** positioned between the first outer portion **1012** and the first inner portion **1014**. In certain exemplary embodiments, the first interface **1016** is circularly shaped and is disposed circumferentially and concentrically between the inner sidewall **1035** and the outer sidewall **1030**. In certain exemplary embodiments, the first inner portion **1014** is non-planar and extends outwardly from the inner sidewall **1035**. In certain exemplary embodiments, the first outer portion **1012** also is non-planar and extends outwardly from the end of the first inner portion **1014** to the outer sidewall **1030**, where the first outer portion **1012** converges into the outer sidewall **1030**. However, in certain alternative exemplary embodiments, one or more of the first outer portion **1012** and the first inner portion **1014** are planar.

Similarly, the second surface **1020** includes a second outer portion **1022**, a second inner portion **1024**, and a second interface **1026** positioned between the second outer portion **1022** and the second inner portion **1024**. In certain exemplary embodiments, the second interface **1026** is circularly shaped and is disposed circumferentially and concentrically between the inner sidewall **1035** and the outer sidewall **1030**. In certain exemplary embodiments, the second interface **1026** is similarly oriented, shaped, and positioned as the first interface **1016** and also is aligned with the first interface **1016**. Thus, the second inner portion **1024** is aligned with the first inner portion **1014** and the second outer portion **1022** is aligned with the first outer portion **1012**. However, in other exemplary embodiments, the second interface **1026** is oriented, shaped, and/or positioned differently than the first interface **1016**. In certain exemplary embodiments, the second inner portion **1024** is non-planar and extends outwardly from the inner sidewall **1035**. In certain exemplary embodiments, the second outer portion **1022** also is non-planar and extends outwardly from the end of the second inner portion **1024** to the outer sidewall **1030**, where the second outer portion **1022** converges into the outer sidewall **1030**. However, in certain alternative exemplary embodiments, one or more of the second outer portion **1022** and the second inner portion **1024** are planar.

At least a portion of the outer sidewall **1030** extending from the first outer portion **1012** to the second outer portion **1022** has a convex-shaped side profile **1032**. However, in other exemplary embodiments, this portion of the outer sidewall **1030** has a different side profile shape, such as planar or concave-shaped, without departing from the scope and spirit of the exemplary embodiments.

In certain exemplary embodiments, the first inner portion **1014** and the second inner portion **1024** are fabricated using a substrate material **304** that extends therebetween to form an inner portion **1080** of the PDC disc cutter **1000**. An intermediate substrate layer **1040** extends outwardly from the inner portion **1080** into an outer portion **1090** of the PDC disc cutter **1000**. The intermediate substrate layer **1040** also is fabricated using the substrate material **304** and is of a non-uniform thickness, according to some exemplary embodiments. The intermediate substrate layer **1040** includes a first side surface **1042** and a second side surface **1044**. The first side surface **1042** faces in the direction of the first surface **1010**, while the second side surface **1044** faces in the direction of the second surface **1020**. The first side surface **1042** extends inwardly into the PDC disc cutter **1000** from the first interface **1016** and continues to a distal end **1046** of the intermediate substrate layer **1040**, which is positioned in the outer portion **1090** near the outer sidewall **1030** in the outer portion **1090**. The first side surface **1042** has a substantially half-parabolic shape; however, this shape is different in other exemplary embodiments. Similarly, the second side surface **1044** extends inwardly into the PDC disc cutter **1000** from the second interface **1026** and continues to the distal end **1046** of the intermediate substrate layer **1040**. The second side surface **1044** has a substantially half-parabolic shape; however, this shape is different in other exemplary embodiments. The distal end **1046** is convex-shaped in certain exemplary embodiments, but is differently shaped, such as being planar or being concave-shaped, in other exemplary embodiments. The distal end **1046** extends around the inner portion **1080** of the PDC disc cutter **1000**.

As previously mentioned, the substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. This substrate material **304** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A cutting table **1060** is formed in the outer portion **1090** and extends from the first side surface **1042** to the first outer portion **1012**, from the second side surface **1044** to the second outer portion **1022**, and from the remaining portions of the intermediate substrate layer **1040**, including the distal end **1046**, to the outer sidewall **1030** in the upper portion **1090**; thereby forming a circumferential portion of the outer sidewall **1030** located in the outer portion **1090**. In certain exemplary embodiments, the cutting table **1060** is formed similarly to the first cutting table **360** (FIG. **3**A) along with any of its several embodiments described.

The PDC disc cutter **1000** is rotatably coupled to a disc bit (not shown). An axle (not shown) mountable, either directly or indirectly, onto the disc bit is inserted through the channel **1039** which allows the PDC disc cutter **1000** to rotate around the axle. The diameter of the channel **1039** is larger than channels formed in prior art rotatable disc cutters since the PDC disc cutter **1000** has a much slower rate of wear than steel or tungsten carbide discs. Thus, the distance between the outer sidewall **1030** and the inner sidewall **1035** can be made smaller. Hence, a larger axle is insertable through the channel **1039**. This larger axle is more durable and has less breakage and/or cracking issues due to its larger diameter size.

In certain exemplary embodiments, the rotating disc cutter **1000** may have a diamond radial bearing surface coated with carbon vapor deposition (CVD) diamond material, or may have polycrystalline diamond radial bearings as are known in the art. If PDC, the inner surface of the disc **1000** is set with PDCs having concave faces which conform to the outer diameter of the axle the disc **1000** is mounted on. The axle may be set with convex PDCs to form a constantly engaged diamond radial bearing.

FIG. **11**A is a top view of a PDC disc cutter **1100** in accordance with a sixth exemplary embodiment of the present invention. FIG. **11**B is a side view of the PDC disc cutter **1100**. FIG. **11**C is a perspective view of the PDC disc cutter **1100**. Referring to FIGS. **11**A-**11**C, the PDC disc cutter **1100** is disc-shaped and includes a first surface **1110**, a second surface **1120**, and a sidewall **1130**, having a substantially uniform thickness, extending from the first surface **1110** to the second surface **1120**.

The first surface **1110** includes a first top portion **1112**, a first bottom portion **1114**, and a first interface **1116** positioned between the first top portion **1112** and the first bottom portion **1114**. In certain exemplary embodiments, the first interface **1116** is a diameter of the first surface **1110** and forms about a 180 degree angle from a first centerpoint **1111** of the first surface **1110**. However, in other exemplary embodiments, the first interface **1116** forms an angle that is either greater than 180 degrees or less than 180 degrees from the first centerpoint **1111**. Additionally, the first interface **1116** is not a diameter of the first surface **1110** in certain exemplary embodiments. The first bottom portion **1114** is substantially planar, but can be non-planar in certain exemplary embodiments. The first top portion **1112** also is substantially planar, but can be non-planar or non-planar with respect to the first bottom portion **1114** and extend towards the second surface **1120** as it extends away from the first interface **1116**.

Similarly, the second surface **1120** includes a second top portion **1122**, a second bottom portion **1124**, and a second interface **1126** positioned between the second top portion **1122** and the second bottom portion **1124**. In certain exemplary embodiments, the second interface **1126** is a diameter of the second surface **1120** and forms about a 180 degree angle from a second centerpoint (not shown) of the second surface **1120**. However, in other exemplary embodiments, the second interface **1126** forms an angle that is either greater than 180 degrees or less than 180 degrees from the second centerpoint. Additionally, the second interface **1126** is not a diameter of the second surface **1120** in certain exemplary embodiments. In certain exemplary embodiments, the second interface **1126** is similarly oriented, shaped, and positioned as the first interface **1116** and also is aligned with the first interface **1116**. Thus, the second bottom portion **1124** is aligned with the first bottom portion **1114** and the second top portion **1122** is aligned with the first top portion **1112**. However, in other exemplary embodiments, the second interface **1126** is oriented, shaped, and/or positioned differently than the first interface **1116**. The second bottom portion **1124** is substantially planar, but can be non-planar in certain exemplary embodiments. The second bottom portion **1124** is substantially parallel to the first bottom portion **1114** in certain exemplary embodiments. The second top portion **1122** also is substantially planar, but can be non-planar or non-planar with respect to the second bottom portion **1124** and extend towards the first surface **1110** as it extends away from the second interface **1126**.

At least a portion of the sidewall **1130** extending from the first top portion **1112** to the second top portion **1122** has a planar side profile **1132** and is arcuately shaped. However, in other exemplary embodiments, this portion of the sidewall **1130** has a different side profile shape, such as convex-shaped or concave-shaped, without departing from the scope and spirit of the exemplary embodiments.

In certain exemplary embodiments, the first bottom portion **1114** and the second bottom portion **1124** are fabricated using a substrate material **304** that extends therebetween to form a lower portion **1180** of the PDC disc cutter **1100**. An intermediate substrate layer **1140** extends outwardly from the lower portion **1180** into an upper portion **1190** of the PDC disc cutter **1100**. According to certain exemplary embodiments, the intermediate substrate layer **1140** extends a greater distance from the lower portion **1180** near the center portion of the lower portion **1180** than near its edges. In these exemplary embodiments, a distal end **1146** of the intermediate substrate layer **1140** is non-planar. The intermediate substrate layer **1140** also is fabricated using the substrate material **304** and is serpentine-shaped, according to some exemplary embodiments. The serpentine-shape includes at least one right angle formed within the shape according to some exemplary embodiments. In certain exemplary embodiments, the serpentine-shape includes at least one curvature formed within the shape. In certain exemplary embodiments, the intermediate substrate layer **1140** includes a first side surface **1142**, which is non-planar, and a second side surface **1144**, which also is non-planar. The first side surface **1142** faces in the direction of the first surface **1110**, while the second side surface **1144** faces in the direction of the second surface **1120**. The first side surface **1142** extends inwardly into the upper portion **1190** of the PDC disc cutter **1100** from the lower portion **1180** and continues to the distal end **1146** of the intermediate substrate layer **1140**, which is positioned in the upper portion **1190**. Similarly, the second side surface **1144** extends inwardly into the upper portion **1190** of the PDC disc cutter **1100** from the lower portion **1180** and continues to the distal end **1146** of the intermediate substrate layer **1140**. The distal end **1146** is planar in certain exemplary embodiments, but is differently shaped, such as being convex-shaped or being concave-shaped, in other exemplary embodiments.

As previously mentioned, the substrate material **304** is a tungsten carbide substrate which is formed from a mixture of tungsten carbide and cobalt powders. This substrate material **304** has been previously described with respect to FIG. **3**A and applies herein with respect to all the described embodiments.

A cutting table **1160** is formed in the upper portion **1190** and extends from the first side surface **1142** to the first top portion **1112**, from the second side surface **1144** to the second top portion **1122**, and from the remaining portions of the intermediate substrate layer **1140**, including the distal end **1146**, to the sidewall **1130** in the upper portion **1190**; thereby forming a circumferential portion of the sidewall **1130** located in the upper portion **1190**. In certain exemplary embodiments, the cutting table **1160** is a polycrystalline diamond table which is formed similarly to the first cutting table **360** (FIG. **3**A) along with any of its several embodiments described.

FIG. **12** is a side cross-sectional view of a portion of a blade **1210** on a disc bit (not shown) illustrating the PDC disc cutters **900** of FIGS. **9**A and **9**B mounted therein in accordance with an exemplary embodiment of the present invention. Referring to FIG. **12**, the disc bit includes a plurality of blades **1210** extending outwardly from a disc bit centerline (not shown). Each blade **1210** includes at least one PDC disc cutter **900** mounted thereto.

Each blade **1210** includes a mounting surface **1212** which generally faces a portion of the wellbore (not shown) once disposed within the wellbore. The mounting surface **1212** generally has a convex-shaped curvature that includes one or more cavities **1214** formed therein. The cavities **1214** are formed during the molding process in forming the blade **1210**. Alternatively, the blade **1210** is formed and thereafter the cavities **1214** are formed therein via drilling or some other known method. Alternatively, the cavities **1214** are formed using other methods known to persons having ordinary skill in the art. Each cavity **1214** is configured to receive a portion of a corresponding PDC disc cutter **900** via brazing or any other known method. Thus, one or more of the PDC disc cutters **900** are fixedly coupled to the blade **1210**. At least a portion of the lower portion **980** of each PDC disc cutter **900** is coupled within the corresponding cavity **1214**, while at least a portion of the upper portion **990** of each PDC disc cutter **900** is exposed beyond the mounting surface **1212**. Thus, at least a portion of the first cutting table **960** is exposed to cut into the wellbore during drilling.

The PDC disc cutters **900** are aligned one after another in the same row and are inserted into each of the corresponding cavities **1214** with adjacently positioned PDC disc cutters **900** being at different depths, thereby providing for cutters **900** having different cutting exposures. For example, alternating PDC disc cutters **900** are inserted at a first depth **1250**, while intervening PDC disc cutters **900**, which are positioned between two alternating disc cutters **900**, are inserted at a second depth **1252** which is different than the first depth **1250**. In certain exemplary embodiments, at least one PDC disc cutter **900** is inserted into a corresponding cavity **1214** at a different depth than at least one other PDC disc cutters **900**. However, in alternative exemplary embodiments, one or more PDC disc cutters **900** are not aligned within the same row. According to some exemplary embodiments, a central axis **1201** of one or more of the PDC disc cutters **900** is oriented substantially perpendicular to the mounting surface **1212**. However, in other exemplary embodiments, the central axis **1201** of one or more PDC disc cutters **900** is oriented non-perpendicularly to the mounting surface **1212**.

FIG. **13** is a top view of two consecutive blades **1310** on a portion of a disc bit **1300** illustrating the PDC disc cutters **300** of FIGS. **3**A and **3**B mounted therein in accordance with an exemplary embodiment of the present invention. Referring to FIG. **13**, the disc bit **1300** includes a plurality of blades **1310** extending outwardly from a disc bit centerline **1302**. Each blade **1310** includes at least one PDC disc cutter **300** mounted thereto.

Each blade **1310** includes a mounting surface **1312** which generally faces a portion of the wellbore (not shown) once disposed within the wellbore. The mounting surface **1312** generally has a convex-shaped curvature that includes one or more cavities **1314** formed therein. The cavities **1314** are formed during the molding process in forming the blade **1310**. Alternatively, the blade **1310** is formed and thereafter the cavities **1314** are formed therein via drilling or some other known method. Alternatively, the cavities **1314** are formed using other methods known to persons having ordinary skill in the art. Each cavity **1314** is configured to receive a portion of a corresponding PDC disc cutter **300** via brazing or any other known method. Thus, one or more of the PDC disc cutters **300** are fixedly coupled to the blade **1310**. At least a portion of the lower portion **380** (FIG. **3**A) of each PDC disc cutter **300** is coupled within the corresponding cavity **1314**, while at least a portion of the upper portion **390** of each PDC disc cutter **300** is exposed beyond the mounting surface **1312**. Thus, the first cutting table **360**, the second cutting table **370**, and an edge of the intermediate substrate layer **340** are exposed to cut into the wellbore during drilling.

According to certain exemplary embodiments, at least one blade **1310** includes a first set **1360** of PDC disc cutters **300** and a second set **1362** of PDC disc cutters **300**. The first set **1360** of PDC disc cutters **300** is substantially similar to the second set **1362** of PDC disc cutters **300**, except that the second set **1362** is positioned differently than the first set **1360**. The first set **1360** is position in a row near a leading edge **1361** of the blade **1310**, while the second set **1362** is substantially positioned in a row behind the first set **1360**, or near a trailing edge **1363** of the blade **1310**, thus becoming back-up cutters in certain exemplary embodiments. At least one of the PDC disc cutters **300** in the second set **1362** is positioned offset from the PDC disc cutters **300** of the first set **1360**. In certain exemplary embodiments, one or more of the PDC disc cutters **300** of the second set **1362** is positioned at the same exposure level, i.e. inserted at the same depth in the blade **1310**, as at least one of the PDC disc cutters **300** of the first set **1360**. In certain exemplary embodiments, one or more of the PDC disc cutters **300** of the second set **1362** is positioned at an under-exposure level, i.e. inserted at a deeper depth in the blade **1310**, than at least one of the PDC disc cutters **300** of the first set **1360**.

FIG. **14**A is a front view of a PDC disc cutter **1400** in accordance with an exemplary embodiment of the present invention. FIG. **14**B is a side cross-sectional view of the PDC disc cutter **1400**. Referring to FIGS. **14**A and **14**B, the PDC disc cutter **1400** is substantially cylindrically shaped, or substantially disc-shaped, and includes a first surface **1410**, a second surface **1420**, and a sidewall **1430** extending from the first surface **1410** to the second surface **1420**. The PDC disc cutter **1400** also includes an upper portion **1490** and a lower portion **1480** that is similar to the upper portion **390** (FIG. **3**B) and the lower portion **380** (FIG. **3**B). PDC disc cutter **1400** is similar to PDC disc cutter **300** (FIGS. **3**A and **3**B), except that a portion of the upper portion **1490** is removed to form a relief area **1495** and a tip **1499**, or apex, that is adjacent to the relief area **1495**. According to some exemplary embodiments, the relief area **1495** is formed using wire electrical discharge machining (EDM) techniques. Alternatively, the relief area **1495** is formed using other known techniques. The wire EDM technique makes cuts in generally two directions, which can be a substantially right angle in some exemplary embodiments. However, the cuts can be made in a single angular direction or in various multi-directions that extend from the tip **1499** to another portion of the upper portion **1490**. According to some exemplary embodiments, the tip **1499** is positioned substantially equidistantly from each end of either a first interface **1416** of the first surface **1410** or a second interface **1426** of the second surface **1420**. However, the positioning of the tip **1499** in the upper portion **1490** is different in other exemplary embodiments. PDC disc cutter **1400** is capable of shearing soft rock formations, such as shale, when coupled to a down hole tool and used in drilling processes. However, when the downhole tool enters harder rock formations, the same PDC disc cutters **1400** on the down hole tool can have additional load applied onto them so that they provide a spalling mechanism to cut the formation. Although PDC disc cutter **1400** is a modification of PDC disc cutter **300** (FIG. **3**A), a similar modification is performed with respect to PDC disc cutter **600** (FIG. **6**A) in other exemplary embodiments.

The PDC disc cutter **1400** is mounted to a bit for drilling subterranean formations. Additionally, in certain exemplary embodiments, these PDC disc cutters **1400**, which are not fully cylindrical disc bits, and other fully cylindrical PDC disc cutters **300**, **400**, **600**, **900**, **1000**, **1100** are both coupled to a bit, either of the same blade, on different blades, in the same area of the bit, or in different areas of the bit. The PDC disc cutters **1400** are coupled to the bit such that these PDC disc cutters **1400** are overexposed, underexposed, or equally exposed with respect to the other fully cylindrical PDC disc cutters **300**, **400**, **600**, **900**, **1000**, **1100**.

PDC disc cutters of this invention allow for the advantageous high point loading and slicing/plowing cutting action of traditional disc bits while overcoming the traditional early failure mechanisms (axle wear/breakage and premature cutter wear) of prior art disc bits. The fixed cutter disc cutter designs accomplish this by dispensing with disc rotation. The rotating designs benefit from large axle holes (and accompanying large wear and breakage resistant axles) made possible by the slow wearing properties of the PDC enhanced discs. Additionally these bits drill with low torque making them ideal for slim hole, coiled tubing drilling, and steerable motor applications where high torque bits can effect tool face orientation or bottom hole assembly integrity. As the fixed cutter PDC disc cutter bits wear their torque signature stays low because their "wear flat" is oriented generally in the circumferential direction rather than in the radial direction as on tradition right circular cylinder PDC shear bits. In addition, in some of the exemplary embodiments, as the cutters wear, the tungsten carbide substrate core of the cutters wears slightly faster than the PDC diamond leaving aggressive knife edges of diamond to attack the formation.

The PDC disc cutters described in the exemplary embodiments provide numerous advantages. These disc cutters are able to withstand higher thrust forces, which lead to increase penetration into the earthen formation that is being drilled. The cutting action of these bits are comparable to the cutting action of traditional surface set natural diamond bits that cut via plowing/grinding/spalling action. The disc bits that use these PDC disc cutters, described herein, are therefore also applicable in hard to very hard formations that currently cannot be economically drilled with existing PDC shear bits. Several versions of the PDC disc cutter, when deployed on a bit face, incorporate a gradual and effective "depth of cut" control mechanism. Spikes in weigh-on-bit are absorbed gradually and smoothly by the curvature and increased surface area of the cutting discs as they are pushed deeper into the formation by the weight spikes.

According to certain exemplary embodiments, the disc cutters can be built in various diameters and one or more than one diameter of rotating, or non-rotating disc can be used on a particular bit's cutting face. Disc cutters can also be augmented by traditional shear cutting PDC cutters, especially on the gage section of the bit. Additionally, a combination of PDC disc cutters and shear cutters can be deployed in advantageous patterns across a bit face to better handle transitional drilling, and passage from softer to harder formation zones.

Further, all design variations known to be applicable to shear cutter bit designs also are applicable to the disc cutter bit designs. These design variations include, but are not limited to, having redundant cutters, serrated cutting patterns, mixed cutter sizes, overlapping cutters, tracking cutters, back-up cutters, shock studs, depth of cut control mechanisms, fluid control and distribution layouts, alternating siderakes, increasing siderakes, decreasing siderakes, varied cutter tip geometries, variations in hydraulic design, variations in nozzle layout, variations in fluid course and cooling channel layout and distribution, variations in diamond thickness, variations in diamond grain size or volume, variations in cobalt content in the diamond, cutter leaching, cutter polishing, variations in diamond to carbide interface, variations in pocket configurations, variations in mounting methods that include brazing, gluing, clamping, and press fitting, bit force balancing optimization, bit work balancing optimization, bits with bi-center designs, the use of disc cutters on hole openers, reamers, expandable reamers, core bits, hybrid bits, casing drilling bits, and others. Although these disc cutters cannot be "backraked" in the traditional sense of a shear cutter, they can be tilted relative to the profile of the bit. The disc cutters, therefore, can be deployed with mixed positive and negative tilts, or increasing or decreasing tilts, or other variations of the tilt.

Although each exemplary embodiment has been described in detail, it is to be construed that any features and modifications that are applicable to one embodiment, whether being a rotatable disc cutter or a fixed disc cutter, are also applicable to the other embodiments. Furthermore, although the invention has been described with reference to specific embodiments, these descriptions are not meant to be construed in a limiting sense. Various modifications of the disclosed embodiments, as well as alternative embodiments of the invention will become apparent to persons of ordinary skill in the art upon reference to the description of the exemplary embodiments. It should be appreciated by those of ordinary skill in the art that the conception and the specific embodiments disclosed may be readily utilized as a basis for modifying or designing other structures or methods for carrying out the same purposes of the invention. It should also be realized by those of ordinary skill in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims. It is therefore, contemplated that the claims will cover any such modifications or embodiments that fall within the scope of the invention.

What is claimed is:

1. A disc cutter, comprising:

a first surface comprising a first upper portion, a first lower portion, and a first interface positioned between the first upper portion and the first lower portion;

a second surface comprising a second upper portion, a second lower portion, and a second interface positioned between the second upper portion and the second lower portion;

a sidewall extending from the perimeter of the first surface to the perimeter of the second surface;

an overall lower portion comprising the first lower portion and the second lower portion and extending therebetween;

an overall upper portion comprising the first upper portion and the second upper portion and extending therebetween;

an intermediate substrate layer extending outwardly from at least a portion of the overall lower portion to a distal end positioned within the overall upper portion, the intermediate substrate layer comprising a first side edge extending from a portion of the overall lower portion to the distal end and facing the first surface and a second side edge extending from a portion of the overall lower portion to the distal end and facing the second surface;

a first cutting table positioned in the overall upper portion and extending from the first side edge to the first upper portion; and

a second cutting table positioned in the overall upper portion and extending from the second side edge to the second upper portion.

2. The disc cutter of claim 1, wherein distal end forms a portion of the sidewall in the upper portion.

3. The disc cutter of claim 1, wherein the overall lower portion and the intermediate substrate layer are fabricated using a substrate material.

4. The disc cutter of claim 3, wherein the substrate material comprises a tungsten carbide.

5. The disc cutter of claim 1, wherein at least one of the first cutting table and the second cutting table is fabricated using a material selected from the group consisting of polycrystalline diamond, synthetic diamond grit, natural diamond grit, and cubic boron nitride.

6. The disc cutter of claim 1, wherein the intermediate substrate layer is half-disc shaped.

7. The disc cutter of claim 1, wherein the first side edge extends from the overall lower portion at a first transition area and the second side edge extends from the overall lower portion at a second transition area, at least one of the first transition area and the second transition area forming about a 90° angle.

8. The disc cutter of claim 1, wherein the first side edge extends from the overall lower portion at a first transition area and the second side edge extends from the overall lower portion at a second transition area, at least one of the first transition area and the second transition area being concave-shaped.

9. The disc cutter of claim 1, wherein the first side edge extends into the overall upper portion from the first interface and wherein the second side edge extends into the overall upper portion from the second interface.

10. The disc cutter of claim 1, wherein the first interface is a diameter of the first surface and the second interface is a diameter of the second surface.

11. A downhole tool, comprising:

at least one blade comprising one or more disc receiving cavities formed therein;

one or more disc cutters, each disc cutter coupled within a corresponding disc receiving cavity, each disc cutter comprising:

an upper disc portion, at least the perimeter of the upper disc portion being fabricated using a material selected from the group consisting of polycrystalline diamond, synthetic diamond grit, natural diamond grit, cubic boron nitride, and impregnated diamond layer;

a lower disc portion fabricated using a substrate material;

an interface positioned between the upper disc portion and the lower disc portion; and

an intermediate substrate layer extending outwardly from at least a portion of the lower disc portion to a distal end positioned within the upper disc portion, the intermediate substrate layer comprising a first side edge extending from a portion of the lower disc portion to the distal end and a second side edge extending from a portion of the upper disc portion to the distal end

wherein at least a portion of the upper disc portion is exposed beyond the cavity, and

wherein at least a portion of the lower disc portion is inserted into the cavity.

12. The downhole tool of claim 11, wherein the upper disc portion is substantially half-moon shaped and wherein the lower disc portion is substantially half-moon shaped.

13. The downhole tool of claim 11, wherein at least one disc cutter is inserted into the blade at a different depth than another disc cutter.

14. The downhole tool of claim 11, wherein a first set of disc cutters is coupled to the blade near a leading edge of the blade and a second set of disc cutters is coupled to the blade behind the first set of disc cutters.

15. The downhole tool of claim 14, wherein one or more cutters of the second set of disc cutters is positioned offset with respect to the positioning of adjacently positioned disc cutters of the first set.

16. The downhole tool of claim 11, further comprising a matrix pocket coupled around a portion of one or more cavities at the surface of the blade, the matrix pocket extending outwardly from the surface of the blade and surrounding a portion of the disc cutter that is closer to a trailing edge of the blade.

17. The downhole tool of claim 11, wherein the one or more disc receiving cavities are formed in a plurality of rows, each disc cutter being coupled to a respective cavity.

18. The downhole tool of claim 1, further comprising one or more shear cutters, the shear cutters being coupled to the blade, the disc cutters and the shear cutters being positioned in an alternating pattern along at least one blade.

19. The downhole tool of claim 11, wherein each blade comprises:

a bit center region comprising one or more shear cutters;

a nose region positioned adjacent the bit center region; and

a shoulder region positioned adjacent the nose region,

wherein at least one of the nose region and the shoulder region comprises one or more disc cutters.

20. The downhole tool of claim 11, wherein each blade comprises:

a gage region comprising one or more shear cutters;

a shoulder region positioned adjacent the gage region; and

a nose region positioned adjacent the shoulder region,

wherein at least one of the nose region and the shoulder region comprises one or more disc cutters.

21. The downhole tool of claim 11, wherein the substrate material is fabricated using a group consisting of tungsten

carbide with a cobalt binder, tungsten carbide with a nickel binder, tungsten carbide with a molybdenum binder, molybdenum carbide, and titanium carbide.

22. The downhole tool of claim **11**, wherein at least one disc cutter is oriented in a sideraked position.

23. The downhole tool of claim **11**, wherein at least one disc cutter is oriented non-perpendicularly with respect to a surface of the blade.

24. A downhole tool, comprising:

a plurality of concentric platforms forming a stair-stepped frusto-conical profile shape, each concentric platform comprising one or more disc receiving cavities formed therein;

one or more disc cutters, each disc cutter coupled within a corresponding disc receiving cavity on one or more of the concentric platforms, each disc cutter comprising:

an upper disc portion, at least the perimeter of the upper disc portion being fabricated using a material selected from the group consisting of polycrystalline diamond, synthetic diamond grit, natural diamond grit, cubic boron nitride, and impregnated diamond layer;

a lower disc portion fabricated using a substrate material;

an interface positioned between the upper disc portion and the lower disc portion

wherein at least a portion of the upper disc portion is exposed beyond the cavity, and

wherein at least a portion of the lower disc portion is inserted into the cavity.

25. The downhole tool of claim **24**, wherein the cavities are formed one or more circular patterns along one or more of the concentric platforms.

26. A disc cutter, comprising:

a substrate material comprising an outer periphery area, the outer periphery area being substantially circumferential; and

a superhard material layer bonded to at least a portion of the outer periphery area.

27. The disc cutter of claim **26**, wherein the disc cutter is deployed on a drill bit for drilling an earthen formation.

28. The disc cutter of claim **26**, wherein the thickness of the superhard material layer ranges from about 0.010 inches to about 0.125 inches.

29. The disc cutter of claim **26**, wherein the superhard material layer comprises a diamond layer, the diamond layer comprising a higher density of diamond at an outer periphery of the diamond layer and a lower density of diamond at an inner periphery of the diamond layer, the inner periphery of the diamond layer being adjacent to the outer periphery area of the substrate material.

30. The disc cutter of claim **29**, wherein the density of diamond progressively decreases from the outer periphery of the diamond layer to the inner periphery of the diamond layer.

31. The disc cutter of claim **26**, wherein the substrate material is fabricated using one of tungsten carbide with a cobalt binder, tungsten carbide with a nickel binder, tungsten carbide with a molybdenum binder, molybdenum carbide, or titanium carbide.

* * * * *